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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

DECEMBER, 1958.

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DROUGHT FEEDING STUDIES WITH CATTLE AND SHEEP

1. The Use of Native Grass Hay (Bush Hay) as the Basal Component of a Drought Fodder for Cattle.

By J. G. MORRIS, M.Agr.Sc., B.Sc., Husbandry Officer, Animal Research Institute, Yeerongpilly.

SUMMARY.

In two experiments, four groups of six beef-type maiden heifers 15-24 months old were group-fed in bare yards a basal diet of long-chaffed bush hay ad lib. with and without supplements.

In one experiment, heifers fed bush hay and a mineral lick ad lib. lost an average of 20 lb. body weight over 26 weeks. Over the same period heifers fed bush hay and a mineral lick with 1.3 lb. or 3.0 lb. lucerne chaff per head per day gained an average of 21 lb. and 83 lb. respectively. Heifers receiving a supplement of 0.41 lb. meatmeal instead of lucerne chaff showed an average weight increase of 39 lb.

In a second experiment, heifers fed the same bush hay without and with a lick ad lib. lost an average of 40 lb. and 48 lb. body weight respectively over a period of 21 weeks. The addition of 1 lb. crushed grain sorghum per head per day to the basal diet with lick ad lib. decreased the weight loss to an average of 14 lb. per head, while the further addition of 2 oz. urea and 0.14 oz. sodium sulphate per head per day permitted a body weight increase of 60 lb. per head.

Nitrogenous supplements (lucerne chaff, meatmeal and urea) increased total dry matter consumption.

In both experiments plasma vitamin A concentration steadily declined while bush hay was fed; the minimum recorded concentration was 16 ug./100 ml. plasma.

The minimum blood inorganic phosphate concentration recorded was 4.2 mg.P/100 ml.

In the second experiment, the ovarian activity of the heifers at the conclusion of bush hay feeding was significantly increased by a supplement of 1 lb. crushed sorghum grain, 2 oz. urea and 0.14 oz. sodium sulphate per head per day.

Heifers which were fed bush hay alone or bush hay and the lick became lethargic and apathetic. Those fed bush hay and nitrogenous supplements remained active.

I. INTRODUCTION.

Beef cattle in Australia are grazed almost universally on native and sown pastures, the growth of which fluctuates markedly with temperature and rainfall. As a result of dependence on pasture growth, periods of nutritional stress occur annually. Throughout much of Australia (Alexander and Chester 1956, Franklin 1956), grazing cattle exhibit a biphasic type of growth curve which is a reflection of this variation in the nutritional plane. In the major beef producing areas of Queensland the net growing season is approximately four months. Chester (1952) stated that cattle usually gain in weight from November to June and lose weight from July to October. A pronounced seasonal pattern in the production of beef results, approximately half the annual beef production being from cattle slaughtered in the three winter months, May to July.

Beef producers in Queensland are faced with even more difficult nutritional problems during recurrent periods of drought. Failure to meet these problems adequately has resulted in heavy loss of production. Recorded losses of cattle (mainly beef cattle) attributed chiefly to drought during 1951 and again during 1956-57 were of the order of 500,000 head (Queensland Government Statistician 1958), and Patterson (1957) showed that during the period 1894-1955 beef cattle numbers in Queensland were closely related to a weighted rainfall index. Kinsman (1953) estimated that the six major droughts in Queensland between 1920 and 1950 reduced the potential production of beef by 8½ per cent.

Supplementary feeding to reduce production losses due to drought has not been widely practised in Queensland. The inadequacy of the fodder reserves held on rural holdings in Queensland is evident from statistics compiled by the Queensland and Commonwealth Government Statisticians. For instance, at the end of March 1957, after a series of seasons generally favourable for fodder conservation, the total recorded fodder stocks on rural holdings were 157,000 tons of hay and chaff, 75,000 tons of silage, and 1,410,000 bus. of grain. The recorded livestock population at that time included 23 million sheep and 7½ million cattle.

As a result of the work of Franklin (1946a, 1946b, 1951, 1952), Franklin *et al.* (1955) and Briggs, Franklin and McClymont (1956, 1957), a considerable amount of information regarding the suitability of rations for the maintenance of sheep during periods of drought is now available. Similar information pertaining to cattle is scanty. This may be one of the reasons for the reluctance to conserve fodder shown by many owners of beef cattle.

The feedstuffs available for the drought feeding of cattle in Queensland may be divided into three groups:

(*a*) Conserved roughages, including conserved native grass pasture (bush hay) and silage and hay made from crops such as sorghum (*Sorghum vulgare*) and Sudan grass (*Sorghum sudanense*).

(*b*) Grains, of which grain sorghum probably has the greatest potential for production and storage on beef cattle properties.

(*c*) Nitrogenous supplements for low quality roughage, including meatmeal, lucerne chaff and urea.

A series of experiments was undertaken to provide information concerning the suitability of a number of these feedstuffs for the drought feeding of cattle under Queensland conditions. This paper is concerned with the use of bush hay fed alone and with various supplements. Two experiments are described. The first was designed to evaluate bush hay as a drought fodder and to examine the effect of the addition of two levels of lucerne chaff and one level of meatmeal to a basal ration of bush hay. At the rate of supplementation employed, the lucerne chaff and the meatmeal supplied approximately equal quantities of crude protein. The second experiment was of a confirmatory nature, but was designed also to evaluate the addition of a salt-boneflour mineralised lick and two iso-caloric supplements of different nitrogen content.

In both experiments, the effects of the rations upon the body weight, feed consumption, coat changes, behaviour and ovarian activity were studied. Blood samples were taken from animals in each group, and blood inorganic phosphate, packed cell volume, haemoglobin, plasma protein, vitamin A, and carotenoid concentrations determined.

II. METHODS AND MATERIALS.

(1) Bush Hay.

The bush hay fed in both experiments comprised part of a cut of 85 tons from 92 acres of pasture on a property in the Central Highlands of Queensland in the autumn of 1954. The pasture, growing on a black earth, was mechanically harvested by a small tractor having an attached power-take-off mower and pulling a ground-driven mower and a side-delivery rake in tandem. This combination of implements delivered the cut pasture into windrows, in which it cured. It was later baled by a mechanical pick-up baler. The hay was stored under cover on the property for approximately 18 months before being despatched for feeding in the first experiment. Hay used in the second experiment had been stored for approximately two years. All hay was chaffed before feeding, the chaffcutter being set to give a cut of half an inch. Chaff was used to reduce wastage in feeding from troughs and to allow accurate measurement of feed intakes.

During the feeding experiments a grab sample was taken from each bag of chaffed hay immediately before feeding. These daily samples were bulked to give a composite sample for chemical analysis.

(2) Lick.

The lick was prepared by intimately mixing 50 lb. of degelatinised bone flour with 50 lb. of coarse salt (sun-dried sodium chloride) over which had been sprayed a solution of 8 oz. of copper sulphate and 2 oz. of cobalt chloride in water.

(3) Experimental Animals.

Beef-type maiden heifers in store condition were used in both experiments. They were inoculated with tenanus toxoid, blackleg vaccine and blood containing the protozoans *Babesia bigemina and B. argentina.* They gave negative reactions to the intradermal caudal fold test for tuberculosis and to serological tests for brucellosis and contagious pleuropneumonia. All animals not polled were dehorned. Sufficient time was allowed for dehorning lesions to heal completely before experimental treatment was commenced. All cattle were free from ticks throughout the experiment.

In the first experiment a line of 30 Hereford heifers, 18–24 months of age, was selected for uniformity of weight on a beef property in Central Queensland. The animals were transported to the Animal Husbandry Research Farm at Rocklea, near Brisbane, and during the next 17 weeks subjected to the necessary inoculations and tests. At the conclusion of this period intractable heifers were eliminated, and from those remaining, four groups each of six animals were selected by stratified random allocation on a body weight and conformation basis. This allowed every animal to be compared with three similar animals in the same weight stratum, thus constituting a quartet.

In the second experiment a line of 30 heifers, predominantly Hereford-Shorthorn cross, was selected for uniformity of body weight on a beef property in Central Queensland. The heifers were transported to Rocklea and over the following nine weeks were subjected to the series of tests and inoculations used in Experiment I.

(4) Body Weight.

At weekly intervals on the same morning as feed residues were removed the body weights were obtained by weighing the individual animals at a standard time (7 a.m. to 8 a.m.) on a cattle weighing scale with an accuracy of $\pm$ 2 lb. Water and bush hay were available *ad lib.* before weighing.

(5) Experimental Yards.

Both experiments were conducted in a unit which comprised a set of four open yards (40 ft. x 48 ft.) of identical design. The yards and an area of 2 ft. around the perimeter of the unit were maintained bare of vegetation by spraying with fuel oil.

Each yard had 28 running feet of troughing, arranged to allow addition of feed without entering the yards. In Experiment I, these troughs were uncovered, but in Experiment II a 12 ft. wide hip roof was provided to protect the feed troughs from the weather. When a lick was fed it was supplied in separate boxes, protected from the weather. Water was available *ad lib.*, one trough in the dividing fence serving two yards. In each yard shade was provided by a structure 10 ft. x 8 ft. with a thatched roof.

(6) Method of Feeding.

For each group in Experiment I two feed troughs, each 7 ft. long, were kept approximately half full by adding the chaffed bush hay thrice daily. Supplements were fed once daily. For Groups II and III the lucerne chaff was fed separately in two troughs each 7 ft. long. For Group IV, the meatmeal was sprinkled over the bush hay.

For each group in Experiment II four feed troughs each 7 ft. long were kept approximately half full by adding chaffed bush hay twice daily. For Groups III and IV the respective supplements were fed once daily by sprinkling on top of the bush hay in the troughs and mixing into the upper layers. The urea and sodium sulphate for Group IV were mixed with the crushed sorghum grain immediately before feeding.

In both experiments uneaten residues of bush hay were removed at weekly intervals and discarded after weighing and sampling for chemical analysis. Lick was added to the boxes at weekly intervals to ensure *ad lib.* consumption.

(7) Methods of Chemical Analysis.

Analytical methods employed were as follows: proximate analysis of feed and faeces, Association of Official Agricultural Chemists (1955); blood inorganic phosphate, Moir (1954); plasma vitamin A and carotenoids, Peirce (1945); carotene in plant material, McGillivray (1952); chromium sesquioxide in faeces, Schurch, Lloyd and Crampton (1950); copper in plant material, Clare, Cunningham and Perrin (1945); blood haemoglobin, Donaldson *et al.* (1951); packed cell volume, Wintrobe (1947); and serum protein, Phillips *et al.* (1950) and Van Slyke *et al.* (1950).

(8) Digestibility of Bush Hay.

Digestibility coefficients of bush hay for sheep were determined by the procedure of Harvey (1952) at the commencement of the cattle pen feeding trial, using the chaffed material from 40 randomly selected bales. Digestibility coefficients for cattle were determined at the conclusion of the feeding phase of Experiment I, using two of the experimental animals from each of Groups I and IV. During the digestibility determinations, cattle were transferred to individual feeding stalls and faeces were collected manually as voided.

For the calculation of apparent digestibility coefficients by difference, the coefficients used for meatmeal were organic matter 92·7 per cent., crude protein 87 per cent. and N.F.E. 100 per cent., and that for the protein in boneflour 50 per cent.

(9) Ovarian Activity Studies.

In Experiment I the ovaries recovered on slaughter were examined for the number of follicles and presence of a corpus luteum, albicans or haemorrhagicum.

In Experiment II the ovaries were scored on the following scale:

0 No activity.

1 Corpus albicans.

2 Small follicles.

3 Developing follicle more than 0·75 cm.

4 Corpus luteum or corpus haemorrhagicum.

The scores of both left and right ovaries were added to give an "ovarian activity score" for each animal.

(10) Coat Studies.

For the assessment of coat texture (pliability of the skin) and woolliness (presence of long curly hair), arbitrary scales scoring from 1 to 5 were employed. The highest figure was for the most pliant skin and the smoothest coat, respectively.

(11) Observations and Recordings.

In both experiments the mean group average body weight and consumption of bush hay and lick were determined at weekly intervals.

Plasma vitamin A and carotenoid concentration changes were determined on the plasma from the heaviest and lightest quartets entering both experiments.

In Experiment I plasma levels were determined at the end of the 2nd, 18th and 21st weeks; in Experiment II at the commencement and termination of the experiment.

Blood inorganic phosphate concentration was determined on all animals in both experiments. In Experiment I the level was determined at the end of the 2nd, 8th, 14th and 21st weeks; in Experiment II at the end of the 17th week.

Serum protein concentration was determined on all animals at the conclusion of both feeding experiments.

Haemoglobin concentration, packed cell volume, coat texture and woolliness were estimated on all animals at the conclusion of the feeding phase of Experiment I.

For three weeks before the conclusion of Experiment I, 120 g. of chromium sesquioxide was intimately mixed with the meatmeal supplement fed daily to Group IV. During the last seven days of this 3-weeks period, samples were collected manually at 7 a.m. and 4 p.m. from the rectum of each animal in this group. The level of chromium sesquioxide in the faeces was used as an index of meatmeal consumption.

Ovaries were recovered from all animals on slaughter: in Experiment I this was 19 weeks after termination of bush hay feeding; in Experiment II at the conclusion of bush hay feeding.

III. EXPERIMENT I.

(1) Design.

The four groups of heifers were confined to bare yards and fed the following rations:

Group I: Bush hay *ad lib.* + lick *ad lib.*

Group II: Bush hay *ad lib.* + lick *ad lib.* + 1·3 lb. lucerne chaff per head per day.

Group III: Bush hay *ad lib.* + lick *ad lib.* + 3·0 lb. lucerne chaff per head per day.

Group IV: Bush hay *ad lib.* + lick *ad lib.* + 0·41 lb. meatmeal per head per day.

Bush hay feeding continued for a period of 26 weeks, after which all but four of the heifers were turned out on pasture for 19 weeks and then slaughtered. These four heifers were from Groups I and IV, and represented members of the

heaviest and lightest quartets entering the experiment. They were fed daily 8 oz. less than the group average intake of bush hay, together with the group average intake of supplements.

(2) Results.

The botanical analysis of the bush hay, presented in Table 1, shows that it is predominantly composed of *Paspalidium globoideum* and *Eriochloa* species.

The chemical composition of composite samples of the bush hay and other feedstuffs as presented to the animals is given in Table 2. The bush hay is high in crude fibre (36 per cent.), low in crude protein (5 per cent.) and devoid of carotene.

Table 1.

Botanical Analysis of Hay from the Central Queensland Highlands (Experiments I and II).

Grass.		Approximate Percentage by Weight.
Paspalidium globoideum	(shot grass)	20
Erichloa sp.	(spring grass)	20
Dichanthium sericeum	(Queensland blue grass)	15
Aristida leptopoda	(white spear grass)	10
Panicum decompositum	(native millet)	5
Panicum queenslandicum	(yabila grass)	
Iseilema membranaceum	(small Flinders grass)	5
Small quantities of *Digitaria brownei*, *Chloris* spp., *Phyllanthus simplex* and unidentified material		25

Table 2.

Proximate Analysis of the Feedstuffs (Experiment 1).

Feedstuff.	Moisture.	Crude Protein.	Ether Extract.	Crude Fibre.	Nitrogen-free Extract.	Ash.	Ca.	P.	SO_4	Cu.	Mo.
	%	%	%	%	%	%	%	%	%	ppm.	ppm.
Bush hay ..	6·6	4·6	1·3	33·4	43·4	10·7	0·29	0·24	0·05	2·9	0·5
	..	*5·0*	*1·4*	*35·7*	*46·5*	*11·4*	*0·31*	*0·26*	..	..	..
Lucerne chaff	10·0	19·7	1·5	23·9	38·0	6·9	1·03	0·33	0·19	4·5	0·6
	..	*21·9*	*1·7*	*26·6*	*42·2*	*7·6*	*1·14*	*0·37*	..	..	..
Meatmeal ..	7·8	62·1	8·9	..	1·5	19·7	5·80	3·12	..	..	..
	..	*67·4*	*9·6*	..	*1·6*	*21·3*	*6·29*	*3·38*	..	..	..

Italics indicate composition on a dry matter basis.

Table 3.

APPARENT DIGESTIBILITY COEFFICIENTS OF THE NUTRIENTS OF BUSH HAY BY SHEEP AND CATTLE (EXPERIMENT I).

Species.	Number of Animals.	Organic Matter.	Crude Protein.	Ether Extract.	Crude Fibre.	Nitrogen-free Extract.
		%	%	%	%	%
Sheep ..	Mean of six animals	42·6	24·1	26·0	54·6	44·7
Cattle ..	Group I—					
	No. A* ..	53·8	36·2	55·0	61·0	50·5
	No. B	48·7	32·1	50·0	54·9	46·0
	Group IV†—					
	No. C	51·5	29·8	48·0	59·2	48·3
	No. D	52·2	29·4	50·0	59·4	50·1

* This animal did not maintain group average intake of bush hay.

† Apparent digestibility coefficients calculated by difference.

Apparent digestibility coefficients of the bush hay by both sheep and cattle are given in Table 3. The sheep digestibility coefficients represent mean figures from six animals fed a diet consisting solely of bush hay. The cattle digestibility coefficients are given for individual animals. The digestibility coefficients for all nutrients determined were greater for cattle than for sheep.

All animals survived the bush hay feeding experiment. The group average changes in body weight, and mean daily bush hay and lick consumption over the 26 weeks of bush hay feeding, are given in Table 4. The weekly group average body weight and bush hay and lick consumption are shown in Fig. 1.

Statistical analyses of body weight at the end of the 8th, 17th and 26th weeks of the experiment, and of overall growth rate, are given in Table 5. There was a significant difference in body weight and growth rate between all groups with the exception of Groups II and IV. These two groups were fed approximately the same amount of crude protein in the supplement.

Feed consumption of all groups exhibited an upward trend during the course of the experiment. The greatest dry matter consumption was recorded by Group III, which received the highest level of protein supplementation.

The wastage of bush hay as uneaten residue accounted for only a small proportion of the bush hay fed. The 26 weeks' average wastage was as follows: Group I, 6·0 per cent.; Group II, 4·0 per cent.; Group III, 3·4 per cent.; Group IV, 1·9 per cent. This indicates that the greater intake of bush hay by Groups II, III and IV was not due to greater selectivity.

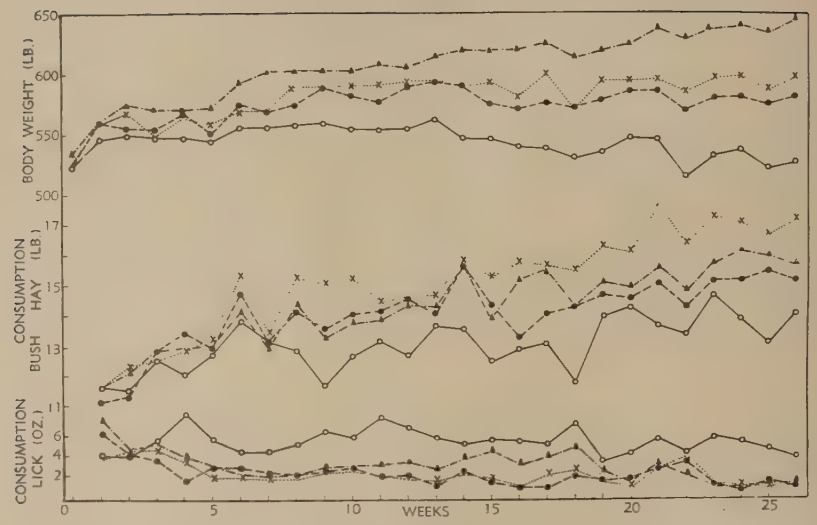

Fig. 1.

Weekly Body Weights and Bush Hay and Lick Consumption of Maiden Heifers Fed Various Supplements (Experiment I).

O———O Group I: Bush hay *ad lib.* + lick *ad lib.*

●— — —● Group II: Bush hay *ad lib.* + lick *ad lib.* + 1.3 lb. lucerne chaff per head per day.

△ — · — △ Group III: Bush hay *ad lib.* + lick *ad lib.* + 3.0 lb. lucerne chaff per head per day.

× ..... × Group IV: Bush hay *ad lib.* + lick *ad lib.* + 0.41 lb. meatmeal per head per day.

The analyses of the residues of bush hay removed from each group at weekly intervals also indicate that there was no selection of portions of the hay. Because of residual meatmeal, the crude protein, calcium and phosphorus contents of the residue from Group IV were higher than in the bush hay as fed.

The ovarian activity 19 weeks after the conclusion of the experiment indicated that the experimental treatment may have influenced the oestral cycle.

The assessment of coat texture and woolliness on the arbitrary scales referred to on page 166 gave the following group mean scoring:

Group.	Mean Score.	
	Coat Texture.	Woolliness.
I	2·2	1·7
II	3·2	2·3
III	3·0	3·5
IV	2·8	2·8

Table 4.

CHANGES IN BODY WEIGHT AND AVERAGE BUSH HAY AND LICK CONSUMPTION OF HEIFERS (EXPERIMENT I).

Group.	Supplements Per Head Per Day.	Body Weight.			Average Daily Intake Per Head over 26 weeks.		
		Initial.	After Feeding Bush Hay.				
			1 Week.	26 Weeks.	Bush Hay.	Lick.	Total Dry Matter.
		lb.	lb.	lb.	lb.	oz.	lb.
I ..	Nil	523	547	527	13·1	5·3	12·5
II ..	1·3 lb. lucerne chaff ..	524	559	580	14·1	2·2	14·5
III ..	3·0 lb. lucerne chaff ..	532	561	644	14·4	2·8	16·3
IV ..	0·41 lb. meatmeal ..	526	558	597	15·2	1·9	14·7

Table 5.

STATISTICAL ANALYSIS OF THE BODY WEIGHTS AND GROWTH RATES OF HEIFERS FED BUSH HAY AND VARIOUS SUPPLEMENTS (EXPERIMENT I).

Groups.	Body Weight at—			Growth Rate over 26 Weeks.
	8 weeks.	17 weeks.	26 weeks.	
III greater than I ..	†	†	†	†
III greater than II ..	NS	*	†	†
III greater than IV ..	NS	NS	*	*
IV greater than II ..	NS	NS	NS	NS
II greater than I ..	NS	*	*	†
IV greater than I ..	*	†	†	†

NS = not significant.
* = $P<0.05$.
† = $P<0.01$.

Table 6.

Blood Inorganic Phosphate, Body Weight Changes, and Chromium Sesquioxide Content of the Faeces of the Six Heifers in Group IV (Experiment I).

Animal No.	Blood Inorganic P (mg./100 ml.).	Body Weight Change.	Cr_2O_3/g. Dry Faeces.
		lb.	
CH2867 ..	8·8	+99	5·4
CH2849 ..	8·3	+57	4·7
CH2845 ..	8·3	+44	4·4
CH2842 ..	6·2	+17	4·3
CH2856 ..	6·2	+38	3·7
CH2862 ..	5·5	−22	2·9

Correlation between :—

Chromium sesquioxide level of faeces and body weight change : $r = 0{\cdot}93$ ($P<0{\cdot}01$).

Chromium sesquioxide level of faeces and blood phosphate : $r = 0{\cdot}88$ ($P<0{\cdot}02$).

Blood inorganic phosphate levels were at all times within the normal range. The minimum recorded value was 4·2 mg.P/100 ml.

When all animals were bled at the end of the 8th, 14th and 21st weeks of the experiment, Group I, which had the highest intake of salt-boneflour lick, on each occasion recorded the highest group mean blood inorganic phosphate level.

Table 6 shows that the level of chromium sesquioxide in the faeces, an index of the intake of meatmeal, for individual animals in Group IV was positively correlated with the blood inorganic phosphate level at the 21st week of the experiment and with the body weight change of the experimental animals.

Repetitive analyses during the course of the bush hay feeding showed a steady fall in plasma carotenoids; plasma vitamin A concentration declined more slowly.

At the conclusion of the bush hay feeding, the lowest individual level recorded was 16·8 μg. vitamin A/100 ml. plasma in an animal from Group I. Packed cell volume, haemoglobin and serum protein determinations did not indicate gross abnormality. Groups III and IV, however, had a greater mean packed cell volume, haemoglobin and serum protein level than Groups I and II.

The behaviour of the animals was affected by the experimental rations. The heifers in Group I, which received only the lick in addition to bush hay, became apathetic and dejected. Those receiving the low level of lucerne chaff (Group II) and meatmeal (Group IV) were much brighter, and those in Group III, on the high level of lucerne chaff, were alert.

IV. EXPERIMENT II.

The objects of Experiment II were to assess the value of the salt-boneflour lick as a supplement to bush hay, and to determine whether the main response to the supplements of meatmeal and lucerne chaff was due to the addition of energy or of protein to the diet.

(1) Design.

The four groups of heifers confined to bare yards were fed the following rations:

Group I : Bush hay *ad lib.*

Group II : Bush hay *ad lib.* + lick *ad lib.*

Group III: Bush hay *ad lib.* + lick *ad lib.* + 1 lb. crushed grain sorghum per head per day.

Group IV: Bush hay *ad lib.* + lick *ad lib.* + 1 lb. crushed grain sorghum, 2 oz. urea and 0·17 oz. sodium sulphate per head per day.

The experiment was terminated after 21 weeks when the supply of bush hay was exhausted. All animals were then slaughtered and their ovaries recovered.

(2) Results.

The chemical analyses of composite samples of the feedstuffs are given in Table 7. The bush hay fed in this experiment had essentially the same chemical composition as that used in Experiment I. The analysis of the crushed grain sorghum showed that it was a typical commercial sample.

All animals survived the experiment. The group average changes in body weight, and mean daily bush hay and lick consumption over the 21-weeks period, are given in Table 8. The weekly group average body weight and bush hay and lick consumption are shown in Fig. 2.

Statistical analyses of the body weights at the 7th, 14th and 21st weeks and the growth rate (Table 9) did not indicate that the lick was beneficial. The supplement of 1 lb. crushed grain sorghum caused a significant retardation ($P<0·05$) of the rate of decline of body weight in Group III. However, a supplement of 2 oz. urea with 0·17 oz. of sodium sulphate in addition to the grain sorghum resulted in an increase in body weight. These animals were significantly heavier at 14 weeks ($P<0·05$) and had a significantly better overall growth rate ($P<0·01$).

The urea and sorghum supplement had the greatest effect upon increasing consumption of bush hay; the group average increase was 3·1 lb. per head per day over that of Group I. The sorghum supplement alone increased

consumption by 1·2 lb. per head per day, whereas the effect of the salt-boneflour lick was negligible, an increase in consumption of 0·3 lb. per head per day over that of Group I.

Table 7.

PROXIMATE ANALYSIS OF THE FEEDSTUFFS (EXPERIMENT II).

Feedstuff.	Moisture.	Crude Protein.	Ether Extract.	Crude Fibre.	Nitrogen-free Extract.	Ash.	Ca.	P.
	%	%	%	%	%	%	%	%
Bush hay	6·4	4·2	0·3	34·4	42·7	12·0	0·26	0·21
	..	*4·5*	*0·3*	*36·6*	*45·9*	*12·7*	*0·27*	*0·22*
Crushed grain sorghum	4·7	10·7	2·8	1·5	78·8	1·5	0·06	0·28
	..	*11·2*	*2·9*	*1·6*	*82·7*	*1·6*	*0·06*	*0·29*

Italics indicate composition on a dry matter basis.

Table 8.

CHANGES IN BODY WEIGHT AND GROUP AVERAGE INTAKE OF BUSH HAY AND LICK BY HEIFERS (EXPERIMENT II).

Group.	Supplements Per Head Per Day.			Group Average Body Weight.			Group Average Daily Intake Over 21 Weeks.		
	Lick.	Crushed Sorghum. (1 lb.)	2 oz. Urea + 0·17 oz. Sodium Sulphate.	Initial.	*After 1 week.	After 21 weeks.	Bush Hay.	Lick.	Total Dry Matter.
				lb.	lb.	lb.	lb.	oz.	lb.
I ..	nil	nil	nil	461	482	442	11·4	—	10·7
II ..	+	nil	nil	462	486	438	11·7	6·9	11·3
III ..	+	+	nil	476	490	476	12·6	3·2	13·0
IV ..	+	+	+	466	485	545	14·5	3·0	14·8

* This increase in body weight over the first week is probably due to rumen "fill."

Table 9.

STATISTICAL ANALYSIS OF THE BODY WEIGHTS AND GROWTH RATE OF HEIFERS FED BUSH HAY ALONE AND BUSH HAY WITH VARIOUS SUPPLEMENTS (EXPERIMENT II).

Groups.	Body Weight at—			Growth Rate over 21 Weeks.
	7 weeks.	14 weeks.	21 weeks.	
IV greater than I ..	†	†	†	†
IV greater than II ..	*	†	†	†
IV greater than III ..	NS	*	†	†
III greater than I ..	NS	NS	NS	*
III greater than II ..	NS	NS	NS	*
II greater than I ..	NS	NS	NS	NS

NS = not significant.
* = $P<0.05$.
† = $P<0.01$.

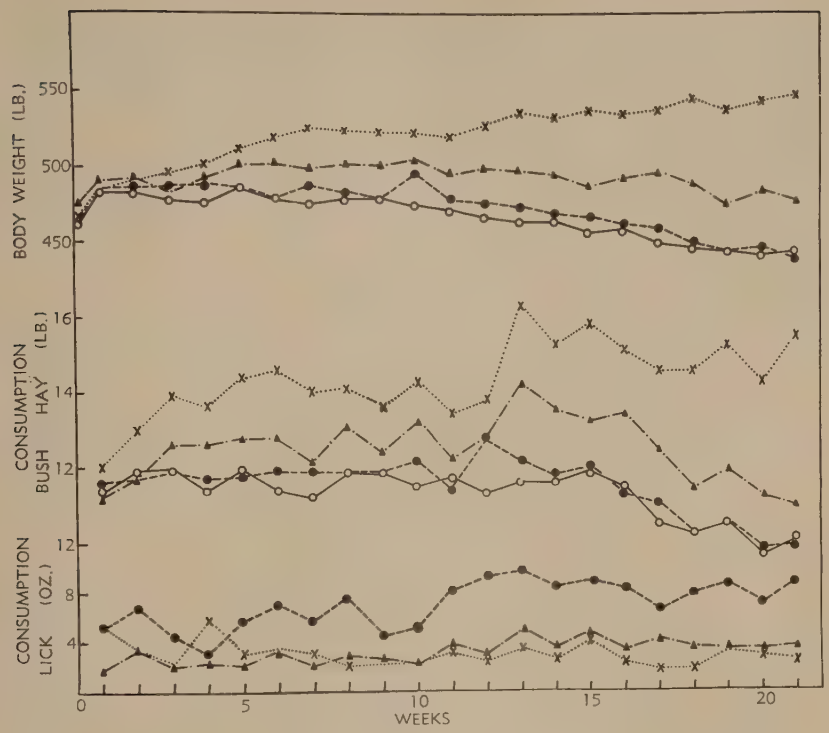

Fig. 2.

Weekly Body Weights and Bush Hay and Lick Consumption of Maiden Heifers Fed Various Supplements (Experiment II).

O————O Group I: Bush hay *ad lib.*

●— — —● Group II: Bush hay *ad lib.* + lick *ad lib.*

△ — · — △ Group III: Bush hay *ad lib.* + lick *ad lib.* + 1 lb. crushed grain sorghum per head per day.

× ····· × Group IV: Bush hay *ad lib.* + lick *ad lib.* + 1 lb. crushed grain sorghum + 2 oz. urea and 0.17 oz. sodium sulphate per head per day.

The wastage of bush hay as uneaten residues accounted for only a small proportion of the bush hay fed. The 21-weeks average wastages were as follows: Group I, 10·8 per cent.; Group II, 10·7 per cent.; Group III, 9·4 per cent.; and Group IV, 6·0 per cent. Chemical analyses of the residues indicated that selection of portion of the hay had not been practised by any of the groups. Thus, increased selection does not account for the greater intake of bush hay by Group IV.

The carotenoid concentration of the plasma declined from an initial mean value of 81 μg./100 ml. to a mean value of 28 μg./100 ml. after 21 weeks. The plasma vitamin A concentration, however, declined at a slower rate: the initial mean value of 37 μg./100 ml. fell to 26 μg./100 ml. after 21 weeks; the lowest recorded value was 16 μg./100 ml.

Blood inorganic phosphate levels recorded at the end of the 17th week were all within the normal range, the minimum value being 6 mg.P/100 ml. The group mean blood inorganic phosphate levels in descending order were Group II, 7·5 mg.P/100 ml.; Group I, 7·2 mg.P/100 ml.; Group III, 7·1 mg.P/100 ml.; and Group IV, 6·1 mg.P/100 ml.

Table 10.

GROUP MEAN "OVARIAN ACTIVITY" SCORE OF FOUR GROUPS OF HEIFERS FED A BASAL DIET OF BUSH HAY WITH VARIOUS SUPPLEMENTS (EXPERIMENT II).

Group.	Mean "Ovarian Activity" Score.	Significant Differences.
I ..	1·8	Group IV > II ($P < 0.01$)
II ..	1·3	Group IV > I ($P < 0.05$)
III ..	3·6	Group III > II ($P < 0.05$)
IV ..	4·5	..

The group average score shown in Table 10 indicates that ovarian activity was significantly affected by plane of nutrition.

The behaviour of the animals was influenced markedly by the experimental rations. The heifers fed bush hay alone or with a salt lick initially became very tractable, then assumed a dejected and apathetic appearance. Their whole concern appeared to be eating, drinking, loafing and lying around. These animals rarely licked their coats. The heifers receiving the supplement of 1 lb. crushed grain sorghum were brighter but not as alert as those which received the additional supplement of urea.

V. DISCUSSION.

These two experiments demonstrate that hay conserved from the native grass pasture of the open black soil downs of the Central Queensland highlands has a potential as a drought fodder. When maiden heifers were confined to bare yards with an ample supply of water, the hay used in these experiments was capable of keeping them alive with only a slight loss in body weight for periods up to six months. Small quantities of high quality supplements fed in addition to bush hay were capable of elevating the combined ration to a maintenance or even to a production level.

In common with all bush hays, the hay used contained a high percentage of crude fibre and a low percentage of crude protein. Hallsworth (1949) showed that there is a negative correlation between the organic matter digestibility and the crude fibre content of feedstuffs. However, the digestibility of the crude fibre component of most subtropical grasses is reasonably high. From the limited number of bush hays examined in Queensland (Marriott and Harvey 1951, Harvey 1952), the apparent digestibility coefficient of the crude fibre is of the order of 50 per cent. This fibre must therefore make a significant contribution to the energy available to ruminants from such feedstuffs.

Although the digestibility data for cattle are limited, the digestibility coefficients of the nutrients in bush hay fed to cattle were, in all cases, higher than those obtained with sheep, a finding which may account for the better performance of cattle compared with sheep when fed the same bush hay (Morris 1958b). The digestibility coefficients of organic matter for the two groups of heifers fed bush hay with and without a meatmeal supplement were similar. This evidence, although derived from only three animals, suggests that meatmeal does not markedly increase the digestibility coefficient of any of the nutrients in bush hay.

It is apparent from Tables 4, 6 and 8 that nitrogenous supplements, meatmeal, lucerne chaff and crushed grain sorghum with urea increased the voluntary intake of bush hay and permitted body weight increase. Within Group IV (Experiment I) the performance of heifers fed bush hay was related to the intake of meatmeal. The content of chromium sesquioxide in the faeces, however, is only an index, being a compounded variable of meatmeal intake, digestibility of the ration and bush hay consumption. The increase in bush hay intake resulting from feeding a predominantly carbohydrate supplement (crushed grain sorghum) was not as great as when the urea was fed simultaneously—1·2 lb. per day against 3·1 lb. per day. It appears that with native subtropical grasses which have relatively high crude fibre digestibility coefficients, nitrogen limits bacterial growth in the rumen and the rate of degradation of the cellulose to volatile fatty acids. If this is valid, nitrogenous supplements increase rate of digestion and thereby increase voluntary consumption of bush hay. Additional evidence to support this will be presented in the results of a later experiment (Morris 1958a), in which a supplement of 2·5 oz. of urea with sodium sulphate resulted in an 82 per cent. increase in the voluntary consumption of sorghum silage by cattle.

Neither the body weight of heifers nor their intake of bush hay was increased by providing a lick containing sterilized degelatinised boneflour sodium chloride and salts of copper and cobalt. The voluntary consumption of lick was reduced to approximately 50 per cent. by feeding a small supplement of meatmeal, lucerne chaff, sorghum grain, or sorghum grain and urea in addition to the bush hay. The high consumption of lick by animals not

receiving any other supplement (Group I in Experiment I and Group II in Experiment II) is probably a reflection of a depraved appetite. Geophagia was observed frequently in these animals. Keys *et al.* (1950) similarly reported a greatly increased hunger for salt in severely under-nourished human subjects. The mean blood inorganic phosphate level of the animals not receiving lick (Group I, Experiment II) was within the normal range. Aphosphorosis cannot account therefore for the luxury consumption of lick. Analysis of the bush hay shows that it contains sufficient calcium and phosphorus to satisfy the allowance of the National Research Council Recommendations (1950) for wintering heifers.

Using the depletion value for calves of 4 μg. of vitamin A/100 ml. plasma given by Eaton *et al.* (1951), plasma vitamin A levels in both experiments indicate that avitaminosis A was not a complicating factor. As the hay was devoid of beta-carotene, the experimental animals not receiving a lucerne chaff supplement were drawing entirely on body reserves. The extent of these reserves will determine the duration for which plasma vitamin A can be maintained above a deficient level. These experiments indicate that, provided maiden heifers have been grazing green pasture prior to the feeding of bush hay, avitaminosis A is not of importance for periods of at least six months. These results are in agreement with those reported by Briggs *et al.* (1956), who showed that 2½-years-old Merino wethers taken from good pasture and fed all-grain rations for seven months did not exhibit avitaminosis A as judged by plasma vitamin A levels.

In Experiment I, there was an indication that heifers fed bush hay and a lick had a lower level of activity in the ovary than heifers fed supplements of lucerne chaff and meatmeal. In Experiment II, significant differences in the ovarian activity score were found when crushed grain sorghum and crushed grain sorghum and urea were added to a basal diet of bush hay. These findings have a practical implication: stronger and heavier animals with greater ovarian activity could be mated at an earlier date after cessation of drought feeding than weaker animals with inactive ovaries.

Studies indicated that coat texture and woolliness were influenced by the experimental treatments. The coats of the heifers in Experiment I were assessed at the termination of the feeding experiment in late summer. Normal cattle grazing good pastures have sleek coats at this time of the year. Yeates (1955) showed by reversible light experiments that a major environmental stimulus to coat shedding of well-nourished cattle is the seasonal variation in the length of daylight. The results of this experiment indicate that the plane of nutrition influences the ability of heifers to react to this stimulus. These findings are in agreement with those reported by Yeates (1958). In Experiment II, which concluded in midwinter when the coat is normally woolly, there appeared to be no group differences in hair cover of the animals.

The dejected and apathetic behaviour of the heifers which received bush hay or bush hay and a lick was common to both experiments. The supplements of lucerne chaff, meatmeal and crushed grain sorghum, especially in conjunction with urea, markedly affected behaviour, resulting in the animals being much more alert and increasing energy expenditure. There was a close similarity in the behaviour pattern of these animals and that reported by Keys *et al.* (1950) for human subjects during semi-starvation.

VI. ACKNOWLEDGEMENTS.

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DROUGHT FEEDING STUDIES WITH CATTLE AND SHEEP

2. The Use of Sorghum Silage With and Without Urea as a Drought Fodder for Cattle.

By J. G. MORRIS, M.Agr.Sc., B.Sc., Husbandry Officer, Animal Research Institute, Yeerongpilly.

SUMMARY.

Four groups each of seven maiden Hereford heifers 15-18 months old were confined in bare yards and fed a basal ration of sorghum silage with and without a urea supplement.

Heifers fed sorghum silage ad lib. **with no supplement lost an average of 70 lb. body weight per head over 28 weeks. Over the same period, a group fed the same amount of silage with 1.5 oz. urea per head per day lost an average of 30 lb. body weight. Groups fed silage** ad lib. **with 1.5 oz. and 2.5 oz. urea per head per day gained an average of 70 lb. and 117 lb. per head respectively.**

Urea supplementation increased silage consumption. The mean daily consumption of dry matter by animals in each group was: no supplement 5.0 lb.; 1.5 oz. urea 8.2 lb.; 2.5 oz. urea 9.1 lb.

Urea-supplemented animals had a higher plasma protein concentration, did not develop the subcutaneous oedema of the submandibular space which occurred in six of the seven heifers in the unsupplemented group, and showed a greater tendency to shed their winter coats.

When 1.5 oz. urea was added to sorghum silage the rate of body weight increase of the animals when turned out to pasture was greater than that of those fed an iso-caloric amount of silage with no supplement.

Heifers which received ad lib. **silage with urea showed normal behaviour; unsupplemented animals on** ad lib. **silage became lethargic, apathetic and dejected.**

I. INTRODUCTION.

For many years small quantities of sorghum silage have been conserved annually on some dairy farms in Queensland and northern New South Wales. With the development of satisfactory mechanical forage harvesters and acceptance of the fact that good silage can be made effectively in trenches or pits, interest in silage-making on a large scale has been stimulated in recent years.

Varieties of sweet sorghum have shown their suitability for silage purposes over a wide geographical range in Queensland. In the pastoral areas, many thousands of tons of this form of silage have been made in trenches on sheep properties but little has yet been made on beef cattle properties.

In view of the potential value of sorghum silage for feeding beef cattle in drought, it was decided to include this feedstuff in drought feeding experiments.

The aim of the experiment reported here was to conserve in underground pits a silage which is comparable in composition to that which has been produced in western Queensland, and to investigate its value as a drought fodder for cattle.

The effect of various levels of a nitrogenous supplement on the body weight of animals fed iso-caloric and *ad lib.* amounts of sorghum silage was studied. Observations on the effect of this supplement upon voluntary comsumption of silage, plasma protein and electrolyte concentrations, plasma volume, behaviour and coat of the animals during the experiment were also made.

Urea, because of its suitability for transportation over long distances, its high nitrogen content and its consequent comparatively low haulage cost per unit of nitrogen, provides a nitrogenous supplement which could be fed to cattle in distant inland areas. As it could also be used to prepare iso-caloric rations of various nitrogen contents for ruminants, it was chosen as the nitrogenous supplement in these experiments.

II. METHODS AND MATERIALS.

(1) Sorghum Silage.

The Sugardrip variety of sweet sorghum was grown at the Animal Husbandry Research Farm, Rocklea, Brisbane, on land that had been under cultivation for a number of years. In order to simulate the low level of available soil nitrogen found in western Queensland no fertilizer was applied. The crop was harvested with a single-row forage harvester and chopper 110 days after planting. At this stage it was approximately 10 ft. high and the seed in the soft to hard dough stage.

The chopped material was placed in a hillside pit silo which was built by excavating on the side of a hill a trench 12 ft. wide at the base, with sloping walls and a floor gradient of 2 per cent. in the direction of the mouth. Approximately 100 tons of chopped material was placed in the pit over a period of eight days and consolidated by frequent rollings with a pneumatic-tyred tractor. The material was then covered with a layer of sawdust approximately 18 in. deep and further rolled.

Four months later the pit was opened at the mouth on a vertical face, and silage removed for feeding.

(2) Experimental Animals.

Thirty dehorned Hereford heifers approximately 15 months of age and in store condition were transported by rail to Rocklea from a beef property

in the Burnett district. During the next four weeks these animals grazed paspalum (*Paspalum dilatatum*) pastures and were tested and inoculated as described by Morris (1958a).

Seven animals were allotted to each of four groups by a stratified random allocation on a body weight basis.

(3) Body Weight.

All animals were weighed by the procedure described by Morris (1958a).

(4) Experimental Yards and Facilities.

The yards and facilities were those described by Morris (1958a).

(5) Methods of Chemical Analysis.

Analytical methods employed were as follows: proximate analysis of feedstuffs, Association of Official Agricultural Chemists (1955); silage quality tests, Watson and Ferguson (1937); plasma protein, Phillips *et al.* (1950), and Van Slyke *et al.* (1950); plasma sodium and potassium, by flame photometry.

(6) Plasma Volume.

Plasma volume was measured by the dilution of Evans blue (T-1824). Twenty minutes after intravenous injection of 20 ml. of 0·5 per cent. solution of Evans blue, a blood sample was withdrawn from the external jugular vein opposite to that injected. The density of the heparinised plasma in this sample was compared with a pre-injection sample at 620 mμ in a Hilger spectrophotometer. The technical precautions described by Gregersen (1944) were observed.

(7) Hair Cover.

Hair cover was estimated by weighing the hair removed by electric clippers from a measured area over the right eighth intercostal space midway between the vertebral and the sternal attachments.

III. EXPERIMENTAL DESIGN.

(1) Treatments.

The four groups of heifers were confined to bare yards and initially subjected to the following experimental rations:

Group I : Sorghum silage *ad lib.*

Group II : Same quantity of silage as eaten by Group I + 1·5 oz. urea* + 0·14 oz. sodium sulphate per head per day.

Group III: Two-thirds the amount of silage eaten by Group I.

Group IV: Two-thirds the amount of silage eaten by Group I + 1·5 oz. urea + 0·14 oz. sodium sulphate per head per day.

* The urea used was "Ureafol" brand of "prilled" urea donated by Imperial Chemical Industries of Australia and New Zealand Limited.

After the experiment had been in progress for four weeks it became apparent that restriction of the silage intake below that of Group I (approximately 5 lb. dry matter per head per day) would not be compatible with survival.

The experiment was therefore modified at four weeks to the following treatments:

Group I : Sorghum silage *ad lib.*

Group II : Same quantity of silage as eaten by Group I + 1·5 oz. urea + 0·14 oz. sodium sulphate per head per day.

(Group I and Group II: not changed from original treatment.)

Group III: Sorghum silage *ad lib.* + 1·5 oz. urea + 0·14 oz. sodium sulphate per head per day.

Group IV: Sorghum silage *ad lib.* + 2·5 oz. urea + 0·18 oz. sodium sulphate per head per day.

For those groups fed silage *ad lib.* (Groups I, III and IV) the amount of silage fed daily was slightly in excess of the intake. Residues were fed back, the previous day's residue being placed on top of the freshly added silage. This procedure prevented deterioration of the silage residue, always ensured *ad lib.* intake and obviated wastage.

Group II was fed daily the same amount of silage as was added to the trough for Group I.

For Groups II, III, and IV the urea and sodium sulphate supplements were sprinkled on the silage and then mixed in with the upper portion of the silage.

At the conclusion of the experimental feeding period on sorghum silage, all animals were transferred to a paspalum pasture.

(2) Observations and Recordings.

Daily dry matter determinations were made on the silage before feeding. These samples were bulked for chemical analysis. The mean weekly dry matter intake was computed for each group from the daily wet silage consumption and the average of the weekly dry matter percentage. Individual body weights were measured at weekly intervals.

At the conclusion of the sorghum silage feeding the following estimations were performed: plasma protein, sodium, and potassium concentrations; clinical examination by an independent observer for subcutaneous oedema: plasma volume of the animals in Groups I and IV; hair cover at the standard site; faecal worm egg counts; recovery rate using body weight as an index.

At the beginning and the end of the period on silage feeding the permanent incisor teeth eruption was recorded.

(3) Duration of the Experiment.

Sorghum silage feeding commenced on July 2, 1957, and continued for a period of 28 weeks. Thereafter, for a period of 12 weeks, the animals grazed a paspalum pasture and recovery rates were measured.

IV. RESULTS.

The proximate analyses of a sample of silage without preparatory drying and one composite sample of silage resulting from the pooling of daily residues after dry matter determination are given in Table 1. The single sample of silage was the result of sub-sampling the material removed by a post-hole auger from three sites in the pit before the commencement of the experiment. These analyses indicate that the composition of the silage fed is similar to the average of a number of sorghum silages prepared in western Queensland and reported by Skerman (1956).

Table 1.

PROXIMATE ANALYSIS OF TWO SORGHUM SILAGE SAMPLES.

Sample.	Moisture.	Crude Protein.	Ether Extract.	Crude Fibre.	Nitrogen-free Extract.	Ash.	Ca.	P.
	%	%	%	%	%	%	%	%
Single* —As taken ..	73·2	1·4	0·4	7·4	15·6	2·0	0·09	0·07
D.M. basis† ..		5·2	1·6	27·5	58·1	7·6	0·31	0·28
Composite‡—D.M. basis ..		4·9	1·4	33·8	50·5	9·4	0·30	0·33

* Sample taken from the pit by an auger prior to the experiment.
† Corrected for loss of volatile material in drying.
‡ Composite sample prepared by drying and bulking a representative sample of the silage fed daily.

The results of silage quality tests performed on the wet silage were as follows: dry matter, 26·8 per cent.; pH, 3·8; lactic acid, 1·13 per cent.; acetic acid, 0·68 per cent.; lactic acid: acetic acid ratio, 1·7:1; total nitrogen, 0·84 per cent. in the dry matter; amino acids, 0·14 per cent. in the dry matter; volatile bases, 0·05 per cent. in the dry matter; and amino acids: volatile bases ratio, 2·68:1. The light-green silage when exposed to the atmosphere did not develop an unpleasant odour. The results of these tests indicate silage of good quality with a low pH and a favourable lactic acid: acetic acid ratio and amino acids: volatile bases ratio.

All animals survived the experiment. The group mean changes in live-weight and group mean daily sorghum silage consumption over the 28 weeks on sorghum silage, and body weight changes during the 12-weeks recovery period

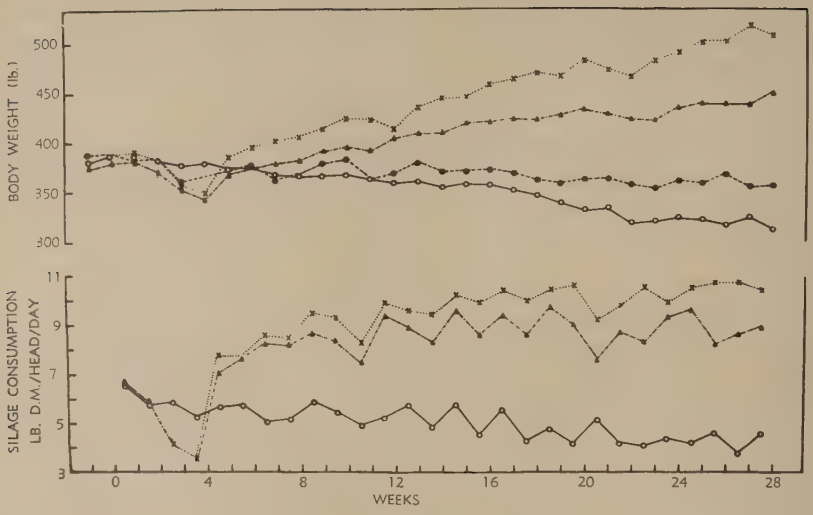

Fig. 1.

Weekly Group Mean Body Weight and Sorghum Silage Consumption of Heifers.

O———O Group I: Silage *ad lib.*

●— — —● Group II: Same amount of silage as eaten by Group I + 1.5 oz. urea and 0.14 oz. sodium sulphate per head per day.

△ — · — △ Group III: Silage *ad lib.* + 1.5 oz. urea and 0.14 oz. sodium sulphate per head per day.

× ····· × Group IV: Silage *ad lib.* + 2.5 oz. urea and 0.18 oz. sodium sulphate per head per day.

on pasture, are given in Table 2. The weekly group mean body weight and silage consumption are shown in Fig. 1. At five weeks the mean body weights of Groups III and IV were approximately the same as those of Groups I and II. In view of the early restriction imposed on silage consumption by Groups III and IV, the calculation of body weight changes in these groups on the modified experimental design should be taken from five weeks after the commencement.

The urea supplement fed to Groups III and IV resulted in a voluntary intake of silage in excess of that of the unsupplemented Group I. After four weeks on *ad lib.* silage, the dry matter consumption of Groups III and IV steadily increased concurrently with body weight increase. The voluntary consumption of silage by Group I, however, steadily declined and was paralleled by a fall in body weight.

The average daily dry matter consumption of Group I during the 28 weeks of silage feeding was 5·0 lb. per head per day. The dry matter consumption of Groups III and IV in excess of that consumed by Group I was 3·2 lb.

Table 2.

GROUP MEAN BODY WEIGHT CHANGES AND DRY MATTER CONSUMPTION OF FOUR GROUPS OF HEIFERS FED SORGHUM SILAGE AND THE SUBSEQUENT GROUP MEAN BODY WEIGHT CHANGES DURING THE RECOVERY PERIOD ON PASTURE.

Group.	Sorghum Silage.	Supplement/head/day.	Body Weight Group Averages.					Silage Consumption D.M./head/day.
			Initial.	After 28 Weeks' Sorghum Silage.	Change.	After 12 Weeks' Pasture.	Change.	
			lb.	lb.	lb.	lb.	lb.	lb.
I	*ad lib.* ..	Nil	383	313	−70	428	+115	5·0
II	Same as fed to Group I*	1·5 oz. urea; 0·14 oz. sodium sulphate	389	357	−32	516	+159	5·0
III	*ad lib.* ..	1·5 oz. urea; 0·14 oz. sodium sulphate	379	449	+70	543	+94	8·2
IV	*ad lib.* ..	2·5 oz. urea; 0·18 oz. sodium sulphate	390	507	+117	577	+70	9·1

* Feed intake adjusted to the same as Group I.

and 4·1 lb. per head per day respectively. The urea supplements fed to Groups III and IV were in the ratio 3 : 5. Thus, the response of silage intake to urea supplementation was less at the higher level.

Comparisons between Groups I and II show that when silage intake was restricted to the same level the supplement of 1·5 oz. urea gave a relatively small response in terms of body weight change. Table 3 shows that the animals in Group II, which received the urea supplement, were significantly heavier

Table 3.

STATISTICAL ANALYSIS OF THE INDIVIDUAL BODYWEIGHTS OF FOUR GROUPS OF CATTLE FED SORGHUM SILAGE ALONE AND WITH VARIOUS RATES OF UREA SUPPLEMENTATION.

Between Groups.	Body Weight at—				Linear Component of Growth Rate.
	7 weeks.	14 weeks.	21 weeks.	28 weeks.	
IV greater than I ..	†	†	†	†	†
IV greater than II ..	†	†	†	†	†
IV greater than III ..	*	*	†	†	†
III greater than II ..	NS	†	†	†	†
III greater than I ..	NS	†	†	†	†
II greater than I ..	NS	NS	NS	*	†

NS = Not significant.
* = $P<0·05$.
† = $P<0·01$.

than those in Group I ($P<0\cdot05$) only at the 28th week of the experiment. The animals in Group III, which were fed the same level of urea as Group II, were significantly heavier than those in Groups I and II ($P<0\cdot01$) after only 10 weeks on *ad lib.* silage. This indicates that the main mechanism by which urea elevates the value of this silage is by an increase in feed consumption.

The group range and mean of the plasma protein concentration are shown in Table 4. All the heifers in Group I had a plasma protein concentration less than that of any animal in the other groups. The plasma protein concentration of the animals in Group II was significantly greater ($P<0\cdot001$) than that of Group I. Both groups ate the same amount of silage, but Group II was given a urea supplement.

Table 4.

Group Mean and Group Range in Plasma Protein Concentration of Four Groups of Heifers Fed Sorghum Silage and Various Levels of Urea.

Group.	Plasma Protein Concentration (g./100 ml. plasma).	
	Group Mean and Standard Deviation.	Group Range.
I ..	5·2 ± 0·12	4·5—5·6
II ..	6·3 ± 0·12	5·9—6·7
III ..	6·6 ± 0·12	6·2—6·9
IV ..	6·7 ± 0·12	6·4—7·0

Groups II, III and IV greater than Group I ($P<0\cdot001$).
Group IV greater than Group II ($P<0\cdot05$).

Neither the within-group nor the between-group variations in plasma protein concentration could be correlated with the plasma sodium or potassium concentration. The range and group mean concentration of these ions in the plasma are given in Table 5.

Table 5.

Group Mean and Group Range in Plasma Sodium and Potassium Concentration of Four Groups of Heifers Fed Sorghum Silage and Various Levels of Urea.

Group.	Group mean (m-equiv./l.).		Group range (m-equiv./l.).	
	Sodium.	Potassium.	Sodium.	Potassium.
I ..	172	5·3	145–185	4·5–6·0
II ..	152	5·5	140–180	5·0–6·0
III ..	160	5·7	148–180	5·0–6·0
IV ..	183	5·2	150–219	5·0–6·0

Clinical examination of all animals for subcutaneous oedema at the conclusion of the experiment showed that this occurred only in Group I and was confined to the submandibular space. Six of the seven animals in this group had oedematous swellings (bottle-jaw), two being classified as severe, two as moderate, and two as slight. The two severe cases of oedema had the lowest plasma protein concentration.

Faecal samples examined for worm eggs gave a maximum count of 80 eggs per gram of faeces. Of these eggs, 94 per cent. were of *Oesophagostomum* species. This indicates that internal parasitism was not a complicating factor in the production of the oedema.

The group mean and range of plasma volumes (millilitres per kilogram bodyweight) of Groups I and IV were as follows:

—	Mean.	Range.
Group I	52	43–63
Group IV	43	40–48

The plasma volume per unit weight of the heifers in Group I was greater than that of those in Group IV.

The behaviour and the attitude of the four groups of animals were markedly affected by the experimental rations. The animals in Group I initially became more tractable, then lethargic and finally apathetic and dejected. The animals in Group II reacted similarly but were less lethargic than those in Group I, while those in Groups III and IV were bright and alert.

The group mean and range in hair cover (expressed as grams per 100 sq. cm. of skin at the standard site) at the end of the period of silage feeding are shown in Table 6. Hair cover of the animals in Group I was significantly

Table 6.

GROUP MEAN AND RANGE IN HAIR COVER AT A STANDARD SITE OF FOUR GROUPS OF HEIFERS FED SORGHUM SILAGE AND VARIOUS LEVELS OF UREA.

Group.	Hair Cover (g./100 sq. cm. skin.)	
	Mean and Standard Deviation.	Range.
I ..	1·8 ± 0·13	0·9—2·1
II ..	1·2 ± 0·13	0·8—1·9
III ..	0·7 ± 0·13	0·1—1·1
IV ..	0·9 ± 0·13	0·8—1·1

Group I greater than Groups III and IV ($P<0.001$).
Group I greater than Group II ($P<0.05$).
Group II greater than Group III ($P<0.05$).

Fig. 2.

Heifers in Group I Fed Sorghum Silage *ad lib.* for 28 Weeks. Note the condition of the animals and the retained winter coat.

Fig. 3.

Heifers in Group IV Fed Sorghum Silage *ad lib.* plus 2.5 oz. Urea and 0.18 oz. Sodium Sulphate Per Head Per Day. These animals were photographed on the same day as those in Fig. 2. Note the condition of the animals, the short coat and coat shedding over the withers and neck.

greater ($P<0{\cdot}05$) than that of those in Groups II, III, and IV. Figs. 2 and 3 illustrate the difference between the coats of the animals in Groups I and IV at the termination of the experiment. The experiment terminated in midsummer (early January), and the hair cover is therefore an index of retention of winter coat.

The skins of the animals in Groups III and IV were noticeably more elastic than those of the animals in Groups I and II. In addition, the skins of the animals in Groups I and II had a dry and scaly appearance, and venipuncture of the jugular, especially in Group I, was difficult.

Examination of the eruption of the permanent incisors indicated that this was not markedly affected by treatment.

V. DISCUSSION.

This experiment indicates that sorghum silage similar in composition to that which has been conserved in western Queensland is a potentially valuable drought reserve fodder for cattle. Though there was a steady decline in body weight averaging 70 lb. per head over seven months, the experimental animals fed silage alone *ad lib.* were still in a strong condition at the conclusion of the experiment and made reasonable weight gains (1·4 lb. per head per day) when turned out on pasture.

The energy requirements for maintenance of cattle may be computed from conventional feeding "standards." Morrison (1951) allows 7·0–7·9 lb. of total digestible nutrients (T.D.N.) and Woodman (1952) 6 lb. of starch equivalent (S.E.) for the maintenance of a 1,000 lb. bovine. Brody (1945) showed that the basal heat production of all animals is proportional to the 0·73 power of body weight. From the above data the average maintenance allowance for the heifers in Groups I and II as they entered the experiment may be computed as 3·5–4·0 lb. T.D.N. or 3·0 lb. S.E. If values of 56·7 lb. T.D.N. (Schneider 1947) and 35 lb. S.E. (J. M. Harvey, personal communication) are assigned to each 100 lb. dry matter (D.M.) in sorghum silage the energy intake of these groups receiving 5 lb. of D.M. is 2·8 lb. of T.D.N. or 1·8 lb. of S.E. The body weight of the heifers in Groups I and II exhibited a slow continuous decline throughout the experiment, and these animals were probably continually in negative energy balance. However, it is apparent that the allowances for maintenance indicated by either the T.D.N. or the production starch equivalent systems are over-estimations of energy requirements for survival of heifers confined to bare yards for periods of at least 28 weeks. Briggs, Franklin and McClymont (1957) also reported that the maintenance allowance of the starch equivalent system is a too liberal estimation of the energy requirement of Merino sheep under conditions of nutritional stress. Similar results have been reported for cattle by Morris (1958b).

A comparison of the same level of silage intake without and with a supplement of 1·5 oz. urea (Group I and Group II respectively) indicated superior performance of the animals receiving the urea supplement. This was reflected in a slower decline in body weight (32 lb. per head over seven months), an elevation in plasma protein concentration, a superior rate of body weight gain when turned out on pasture (1·9 lb. per head per day) and a greater

tendency to shed the winter coat (Tables 2, 4 and 6). As the energy value of urea to ruminants is zero, the superior performance of the animals receiving the same intake of silage with added urea may be explained either by an increased efficiency of utilisation of the energy in silage, possibly by an increase in digestibility, or by a tissue protein sparing effect of urea. The latter explanation appears more acceptable in view of the recorded hypo-proteinaemia of Group I and superior weight gain by Group II during the recovery phase on pasture. This apparent slower rate of body weight increase by Group I during the recovery period may at least be partly explained by the elimination of oedematous fluid. This excessive fluid retention also tends to mask the true decline in body weight during the period of silage feeding. Methods for *in vivo* estimation of total body water of ruminants have inherent difficulties. Blaxter and Rook (1953) have reported that the antipyrine technique is not satisfactory with the bovine. Similarly, Morris (1954) reported that variations in rate of metabolism of antipyrine and its entry into the rumen and abomasum seriously limited the application of this technique to sheep.

The addition of a supplement of urea when silage was fed *ad lib.* greatly increased voluntary silage consumption and permitted body weight increase. The silage consumption by Groups III and IV also exhibited a steady increase throughout the experiment, corresponding to the increase in body weight. Similarly, the *ad lib.* consumption of silage by Group I slowly declined with the corresponding decline in body weight. It is suggested that the supplement of urea increased silage consumption by providing nitrogen which was limiting bacterial growth and hence rate of fermentation in the rumen. Morris (1958a) reported a similar increase in the voluntary intake of native grass hay (bush hay), resulting from the addition of supplements of vegetable protein (lucerne chaff), animal protein (meatmeal), and urea with grain sorghum. Urea has practical advantages as a source of additional dietary nitrogen. These include lower transport costs per unit of nitrogen and high solubility in water which permits application as a spray to the roughage.

The addition of urea to the diet of cattle on a restricted level of silage intake maintained their plasma protein concentration and prevented the development of subcutaneous oedema. Urea also exerted a similar effect at greater levels of silage consumption. Decreased plasma protein concentration as a result of low-protein diets has been reported in rats by Kohman (1920) and Frisch, Mendel and Peters (1929), and in dogs by Weech, Goettsch and Reeves (1935). It is apparent from the reviews of Keys *et al.* (1950) and Gilman and Gilman (1951) that the famine oedema syndrome is not necessarily explicable on the basis of a lowering of plasma protein concentration. In this experiment with cattle, the plasma protein concentration of all animals on the low-"protein" diet (Group I) was less than that of any other animal on the higher "protein" (urea supplemented) diets. The two animals with the severe

oedema had the lowest recorded plasma protein concentrations. But there was no correlation between the degree of oedema of the submandibular space and the plasma protein concentration of the other animals in Group I. There was no apparent relationship in any of the animals between oedema and the plasma sodium or potassium concentrations. The products of the mean plasma protein concentration and mean plasma volume per unit body weight for Groups I and IV were similar.

Keys *et al.* (1950) reported that lethargy, reluctance to move except to eat and drink, and a disregard for personal hygiene, are typical reactions of the human subject undergoing dietary restrictions. It is of interest to note the close similarity between this behaviour pattern and that of the animals in Groups I and II. Lethargy and restriction of movement, both voluntarily and by confinement to yards, would minimise energy expenditure. If this was coupled with a similar reduction in basal metabolic rate as observed in humans, it would permit maintenance of life for protracted periods on a low energy intake. These factors may play an important role in the drought feeding of cattle. The virtual absence of normal coat licking by the animals in Groups I and II may be a reaction in bovines similar to the disregard for personal hygiene by humans during semi-starvation.

Hair cover measurements indicate that the animals in Group I did not shed their winter coat. The long hair on the animals in Group I could be readily detached from the skin, indicating that the mechanism causing removal of the hair was defective. The significance of licking and skin movement in the removal of this hair was not investigated.

Yeates (1955) has shown by reversible light experiments that coat shedding in well-nourished bovines is conditioned by length of daylight. The results of this and a similar experiment reported by Morris (1958a) indicate that the phenomenon of coat shedding is modified also by the plane of nutrition. These findings are in agreement with those reported by Yeates (1958).

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DROUGHT FEEDING STUDIES WITH CATTLE AND SHEEP

3. A Preliminary Note on the Use of Grain Sorghum as a Drought Fodder for Cattle.

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SUMMARY.

Eight beef-type heifers, 15-18 months old, fed for 27 weeks on 3 lb. crushed grain sorghum supplemented with ground limestone were in strong condition at the conclusion of the feeding period and made rapid weight gains when returned to pasture.

The mean loss of body weight during the first nine weeks of all-grain feeding was 10 lb. per head per week; over the final 18 weeks it was 3.3 lb. per head per week.

Serum protein, packed cell volume, plasma volume, and plasma sodium, potassium and chloride concentrations did not appear to be markedly influenced by the ration.

I. INTRODUCTION.

Franklin (1954) and Franklin, McClymont, Briggs and Campbell (1955) have shown that under experimental drought feeding conditions sheep may be successfully maintained on rations containing a high proportion of cereal grain. The omission of roughage, and use of all-grain rations for the drought feeding of sheep, was later reported by Briggs, Franklin and McClymont (1956).

Our present knowledge regarding the feed requirements of the bovine for survival is limited. Morris (1958a,b) has reported on the use of two roughages—native grass hay (bush hay) and sorghum silage—for the drought feeding of cattle. The purpose of this communication is to report some preliminary work on the use of grain sorghum, without the addition of roughage, as a drought fodder for cattle. Observations were made on the effect of the all-grain ration on body weight; serum protein concentration; plasma sodium, potassium and chloride concentrations; packed cell volume; plasma volume; and behaviour of the animals.

II. METHODS AND MATERIALS.

(1) Experimental Animals.

Eight dehorned Hereford or Hereford-dairy cross heifers, in store condition and 15–18 months of age, were taken from paspalum (*Paspalum dilatatum*) pasture, weighed, and housed in individual stalls with a concrete

floor. These animals had previously been inoculated with a tetanus toxoid and blackleg vaccine, and dipped in a 0·5 per cent. DDT solution. They were negative to the single intradermal test for tuberculosis and to serological tests for brucellosis and contagious pleuropneumonia.

(2) Method of Feeding.

For 11 days after transference to stalls, a restricted ration of lucerne hay was fed. By the end of this period the animals appeared accustomed to stall conditions and could operate the automatic drinkers. The ration was then changed over a period of three weeks according to the following schedule until an all-grain diet was being fed.

Number of Days on Ration.	Ration (lb./head/day.)	
	Grain sorghum.	Lucerne chaff.
4	2	4
4	2½	3
4	2½	2
5	2¾	1½
4	3	½
189	3	0

The daily ration of 3 lb. crushed grain sorghum was fed between 7 a.m. and 8 a.m. except on the days on which the animals were weighed, when it was fed at 3.30 p.m. When all-grain feeding commenced, 1 per cent. calcium carbonate was intimately mixed with the grain. No salt or other additives were included. Drinking water was available *ad lib.* from the Brisbane city supply.

After 189 days (27 weeks) of all-grain feeding, the animals were returned to paspalum pasture.

(3) Body Weight.

The eight heifers were individually weighed at weekly intervals between 7 a.m. and 8 a.m. After weighing, the heifers were confined to a bare unshaded yard until 3 p.m. and then returned to the stalls.

(4) Methods of Chemical Analysis.

Proximate analysis of sorghum grain was by the methods of Association of Official Agricultural Chemists (1955), and serum protein concentration was determined by a combination of the methods of Phillips *et al.* (1950) and Van Slyke *et al.* (1950).

Plasma electrolytes were estimated on samples of blood collected from the external jugular vein. Heparin was used as an anticoagulant. These blood samples were centrifuged as soon as possible after collection to minimise exchange of chloride, sodium and potassium ions between plasma and cells. For the estimation of plasma sodium and potassium the plasma was diluted with distilled water 1 in 500 and 1 in 50 respectively and read directly on a calibrated E.E.L. flame photometer. Plasma chloride was estimated by adding to 5 ml. of plasma, 10 ml. of distilled water and then 5 ml. of 20 per cent. trichloracetic acid, shaking the mixture and allowing it to stand for 10 minutes. After filtering through a No. 40 Whatman filter paper, a 5 ml. aliquot of the filtrate was titrated electrometrically for chloride against a standard silver nitrate solution. A blank determination using distilled water in place of plasma was used to correct for the chloride content of the reagents used.

Packed cell volume was determined by the method described by Wintrobe (1947), and plasma volume by the dilution of Evans blue (T-1824) as described by Morris (1958b).

III. RESULTS.

The introduction of heifers to a ration of all-grain was achieved without incident. There was some looseness of the faeces, but at no time did diarrhoea occur. As the experiment progressed the faeces assumed a semi-solid nature, but at the conclusion of the experiment portions of undigested grain were still apparent. No metabolic disorders were apparent clinically, either in the introductory period, during all-grain feeding, or when turned out on pasture.

In Fig. 1 the group average body weights at weekly intervals are shown. Actual mean body weights at selected dates were as follows:

Period.	Mean Group Weight.
	lb.
From pasture	580
Commencement of all-grain feeding	564
After 9 weeks all-grain feeding	472
After 18 weeks all-grain feeding	449
After 27 weeks all-grain feeding	412
After 6 weeks on pasture	584
After 8 weeks on pasture	625

Values for the serum protein, packed cell volume, plasma volume and plasma sodium, potassium and chloride concentrations after 27 weeks of all-grain feeding are given in Table 1.

Table 1.

SERUM PROTEIN, PACKED CELL VOLUME (P.C.V.), PLASMA VOLUME AND PLASMA SODIUM, POTASSIUM, AND CHLORIDE CONCENTRATION OF HEIFERS AFTER 27 WEEKS OF ALL-GRAIN FEEDING.

Animal No.	Serum Protein g./100 ml.	P.C.V. %	Plasma Volume (ml./kg. body weight).	Plasma Electrolytes m-equiv./l.		
				Sodium.	Potassium.	Chloride.
1 ..	7·4	40	47	125	5·0	116
2 ..	6·1	36	46	161	4·5	130
3 ..	6·3	38	54	150	5·0	125
4 ..	5·8	39	52	135	3·8	122
5 ..	6·7	39	45	140	5·0	128
6 ..	6·8	37	45	138	5·0	122
7 ..	5·6	36	54	125	5·0	114
8 ..	5·6	37	*	130	5·0	104
Mean	6·3	38	49	138	4·8	120

* Not determined.

Rumination ceased within two weeks on the all-grain ration, and recommenced at least in some heifers on the day they were turned out to pasture. With the cessation of rumination on all-grain feeding, the heifers were observed to spend considerable time chewing the 1 in. steel bar over the feed trough. This behaviour was similar to rumination except that a bolus was not regurgitated for re-mastication.

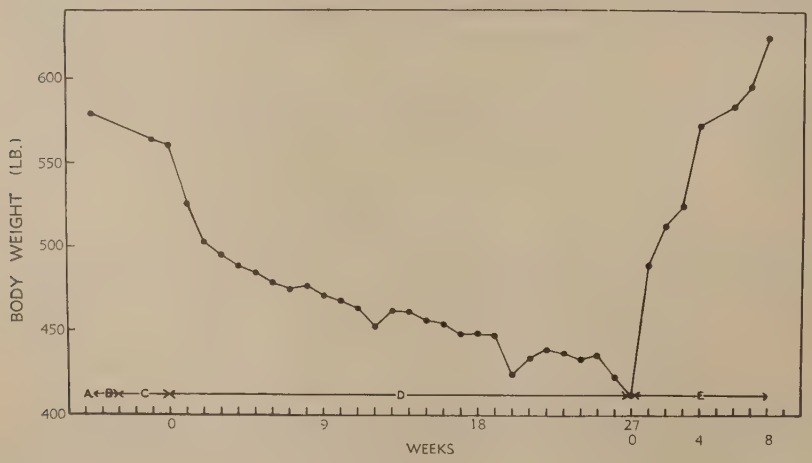

Fig. 1.

Changes in Body Weight of Heifers Prior to, During and After Feeding 3 lb. Crushed Sorghum Per Head Per Day. A., pasture, B., restricted lucerne hay ration. C., grain-lucerne mixture. D., all-grain. E., recovery on pasture.

After the experiment had been in progress for some weeks, the environment of the animals had a smell reminiscent of a pig sty.

Proximate analysis (expressed as percentages) of a sample of the sorghum grain was as follows: moisture 10·0, crude protein 10·1, ether extract 2·6, crude fibre 1·5, nitrogen-free extract 74·5, ash 1·5, calcium (Ca) 0·05, phosphorus (P) 0·27, sodium (Na) 0·04, and potassium (K) 0·13.

IV. DISCUSSION.

This preliminary experiment has demonstrated that cattle can survive without apparent metabolic or digestive upsets, other than cessation of rumination, for periods up to 27 weeks on a grain sorghum ration without any roughage.

At the level of feeding practised (3 lb. per head per day) there was considerable loss of body weight, especially in the first nine weeks of the all-grain feeding. After this period the rate of weight loss declined. This weight loss, however, did not adversely affect the animals' ability to regain body weight rapidly when returned to pasture. Part of this apparent rapid weight loss and gain is due undoubtedly to rumen "fill".

Maintenance energy requirements of cattle may be assessed from conventional feeding "standards". For a 1,000 lb. cow, Morrison (1951) allows 7·0–7·9 lb. of total digestible nutrients (T.D.N.), and Woodman (1952) allows 6·0 lb. of starch equivalent (S.E.). Brody (1945) has shown that the basal heat production of all animals varies as the 0·73 power of body weight. By applying this general relationship the mean maintenance energy requirements of the heifers at the commencement and termination of grain feeding may be computed as:—commencement 4·6–5·2 lb. of T.D.N. or 4·0 lb. of S.E.; termination 3·7–4·1 lb. of T.D.N. or 3·1 lb. of S.E.

The energy intake from 3 lb. of air-dried crushed sorghum is 2·2 lb. of T.D.N. or 2·0 lb. of S.E. if the values of 72 lb. of T.D.N. (Schneider 1947) and 68 lb. of S.E. (Hewitt 1949) per 100 lb. of air-dried material are adopted.

Although energy balance was probably not attained at any time during this experiment, the results indicate that the maintenance allowance given by feeding "standards" may over-estimate the survival requirements of cattle under stall conditions for periods up to 27 weeks. Briggs, Franklin and McClymont (1957) reported that "overseas feeding standards are too liberal when applied to the Australian Merino sheep under conditions of nutritional stress".

Serum protein levels at the conclusion of the experiment indicated that with the exception of three animals (Nos. 1, 5 and 6) the values were below 7·0 ± 0·5 g./100 ml. recorded by Bradish, Henderson and Brooksby (1954) for normal Devon steers of comparable age.

Packed cell volumes of all animals were within the range of 30–40 per cent. reported by Coffin (1953), but tended to be greater than the value of 33·7 per cent. recorded by Holman (1955).

Plasma volume of all animals was greater than the range of 36·3–40·6 ml./kg. cited by Reynolds (1953) for non-pregnant, non-lactating cows in good condition. The disparity between the values found for these experimental animals and those cited by Reynolds may be due to the effect of rumen "fill" on body weight. Taking the average plasma volume at the conclusion of the period on grain feeding and the average body weight one week after being on pasture, a value of 41·2 ml./kg. is computed. This approximates closely to the upper limit cited by Reynolds. Considering this value in relation to the condition of the animals the indications are that plasma volume was not elevated.

Our present knowledge of the sodium and chlorine requirements of bovines is limited. Work at Onderstepoort by Theiler, Green and Du Toit (1927) indicated that the growth of heifers was not affected by a ration providing only 1·5 g. of sodium and 5 g. of chlorine daily but there were calving abnormalities. Du Toit, Malan and Groenewald (1934) showed that a ration providing a daily intake of 4·2 g. sodium (Na) and 6·7 g. chlorine (Cl) was sufficient for dry cows but not for lactating cows. From the experiments at Onderstepoort (Theiler *et al.* 1927 and Du Toit *et al.* 1934), Du Toit *et al.* (1940) suggest that 1·5 g. sodium and less than 5 g. chlorine daily are sufficient for growth. These requirements of sodium and chlorine for growth are met by a ration containing 0·02 per cent. sodium and 0·07 per cent. chlorine for a dry matter intake of 16 lb. per head per day.

Cereal grains have a low sodium concentration in comparison with other feedstuffs. Barham *et al.* (1946) analysed a number of American varieties of grain sorghum: the sodium concentration was within the range of 0·014–0·041 per cent., with a mean of 0·023 per cent. Analysis of the sorghum grain fed in this experiment shows it contained 0·04 per cent. sodium and 0·13 per cent. potassium. At the level of feeding adopted in this experiment, this analysis shows a mean dietary intake of 0·49 g. sodium per head per day, which is approximately one-third the requirements for growth cited by Du Toit *et al.* (1940).

Plasma sodium concentration of six of the eight heifers after grain sorghum feeding was below the range 145–219 m–equiv./l. reported by Morris (1958b) for heifers of similar age. The values for plasma sodium which were

found conform more closely to those reported by McSherry and Grinyer (1954) of 142 ± 5 m–equiv./l. for serum of cattle 2–13 years of age, and by Murty and Kehar (1952) of 153–489 mg./100 ml. (110–213 m–equiv./l.) for the Kumaoni bullock.

Plasma chloride concentrations of all animals with the exception of No. 8 were in excess of the range of 356–386 (mean 371) mg./100 ml. reported by Lengemann, Aines and Smith (1952) for Holstein females of comparable age and the value of 103·7 ± 3·5 m–equiv./l. of McSherry and Grinyer (1954) for cows 2–13 years of age. From these results it appears that the chloride intake from crushed grain sorghum and drinking water was sufficient to prevent a depression of plasma chloride concentration.

Plasma potassium concentration with the exception of that of animal No. 4 conforms to the value of 4·85 ± 0·47 m–equiv./l. reported by McSherry and Grinyer (1954).

The effect of the addition of salt (sodium chloride) on the well-being, plasma sodium, potassium and chloride concentrations and extracellular fluid volume of cattle fed a sole diet of grain sorghum is being further investigated.

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DROUGHT FEEDING STUDIES WITH CATTLE AND SHEEP

4. The Use of Native Grass Hay (Bush Hay) and Sorghum Silage as Basal Components of Drought Fodders for Sheep.

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SUMMARY.

Four groups of 2-4-tooth Merino wethers were group-fed basal rations of either native grass hay (bush hay) ad lib. or sorghum silage ad lib. in bare yards with shade and water.

Wethers fed bush hay only for 19 weeks lost 20 per cent. of their initial body weight. Supplementation with either a salt-boneflour lick alone or with 2.3 oz. crushed sorghum per head per day did not markedly decrease body weight loss. Additional supplementation with 8 g. of urea and 0.6 g. of sodium sulphate per head per day reduced body weight loss to half of that of the unsupplemented group.

Wethers fed sorghum silage only for 22 weeks lost 30 per cent. of their initial body weight. The addition of 8 g. of urea + 0.8 g. sodium sulphate or 16 g. of urea + 1.6 g. sodium sulphate per head per day significantly decreased body weight loss. Urea supplementation increased silage consumption but the increase in wool growth was not significant.

Survival rate during bush hay feeding was 100 per cent. with a 4 per cent. mortality when sheep were returned to pasture. During sorghum silage feeding the mortality rate was 4 per cent. with a 100 per cent. recovery of survivors on pasture. Sheep fed sorghum silage recovered their body weight rapidly when returned to pasture.

A comparison was made of the performance of sheep and cattle fed the same basal diets of bush hay and sorghum silage. Sheep lost a greater percentage of their initial body weight, and showed a smaller response to urea supplementation.

I. INTRODUCTION.

As a result of the experiments of Franklin (1946a,b; 1952), Franklin *et al.* (1955), and Briggs, Franklin and McClymont (1956, 1957), a considerable amount of information on the drought feeding of sheep with rations containing a high proportion of grain is now available. The use of cereal chaff and straw as basal components of drought rations for sheep has been reported by Franklin, Briggs and McClymont (1955) and Briggs (1956).

Morris (1958a,b,c) has reported a series of experiments to investigate the value of native grass hay (bush hay), sorghum silage and grain sorghum as basal components of drought fodders for cattle. In the course of this work groups of sheep and cattle were fed the same basal ration and the same supplements.

In this paper the results of two experiments using bush hay and sorghum silage as basal components of drought fodders for sheep are reported. The effect of the rations upon the survival rate, changes in body weight and feed consumption of Merino wethers was studied. In the sorghum silage feeding experiment, wool production was also measured. A comparison of the performance of cattle and sheep fed the same basal rations and supplements is made.

II. METHODS AND MATERIALS.

(1) Experimental Animals.

In both experiments Merino wethers in store condition with two to four permanent incisor teeth were used as experimental animals. Prior to the experiment all sheep were inoculated with tetanus toxoid and blackleg vaccine and drenched with phenothiazine. Animals with dental abnormalities were rejected.

In the first experiment four groups of six wethers were selected by stratified random allocation on a body weight basis.

In the second experiment four groups of 13 wethers were selected by the same procedure from a line of 59 wethers originally selected from a flock for uniformity of weight. All sheep were shorn four weeks prior to the commencement of the experiment.

(2) Body Weight.

Body weight was recorded at weekly intervals between 7 a.m. and 8 a.m. by weighing the individual sheep on a cattle-weighing scale.

(3) Wool Growth Measurements.

Wool growth was measured on all sheep in the second experiment. A rectangular area 15 cm. by 10 cm. was tattooed over the right flank. At 2-monthly intervals this area was clipped and the weights of greasy and scoured wool recorded.

(4) Feedstuffs.

The bush hay which constituted the basal ration in the first experiment was portion of the same line of hay which was fed to cattle in Experiment II reported by Morris (1958a). In common with other mature native grasses in Queensland, this hay had a low crude protein content (4·5 per cent. on a dry matter basis). A description of the method of haymaking and botanical and chemical composition were reported by Morris (1958a). The bush hay was fed chaffed (average length 0·5 in.).

The sorghum silage fed to sheep was taken from the same pit over the same period as the silage fed to cattle in the experiment reported by Morris (1958b). This silage had a low crude protein content (5·2 per cent. on a dry matter basis).

The salt-boneflour mineralised lick was prepared by the method described by Morris (1958a).

(5) Experimental Yards.

Both experiments were conducted in a unit of four open yards each 16 ft. x 32 ft. These yards were kept devoid of vegetation by spraying with fuel oil. A galvanised iron roof 8 ft. x 8 ft. insulated with dry grass provided shade and protected the feed troughs and lick boxes from the weather. Each yard had two feed troughs each 3 ft. long. Water was available *ad lib.*

III. EXPERIMENT I.

(1) Design.

The four groups of six wethers were fed the following rations:—

Group I : Bush hay *ad lib.*

Group II : Bush hay *ad lib.* + lick *ad lib.*

Group III: Bush hay *ad lib.* + lick *ad lib.* + 2·3 oz. crushed sorghum grain per head per day.

Group IV: Bush hay *ad lib.* + lick *ad lib.* + 2·3 oz. crushed sorghum grain + 8 g. urea and 0·6 g. sodium sulphate per head per day.

At the end of each week the uneaten residue of bush hay was removed, weighed and discarded after sampling for chemical analysis.

The duration of bush hay feeding was 19 weeks, at the end of which time all sheep were allowed to graze *Paspalum dilatatum* pasture.

(2) Results.

All sheep survived the period on bush hay feeding. Mean group body weight changes and group average consumption of bush hay and lick are given in Table 1. The weekly mean body weight and bush hay and lick consumption are shown in Fig. 1.

The linear growth rate for each group was not statistically different at a probability of $P<0·05$.

Results of the analysis of composite group samples of the residues of bush hay showed that for Groups I, II and III the residue had a lower crude protein content than the hay as fed. Analysis of the residue from

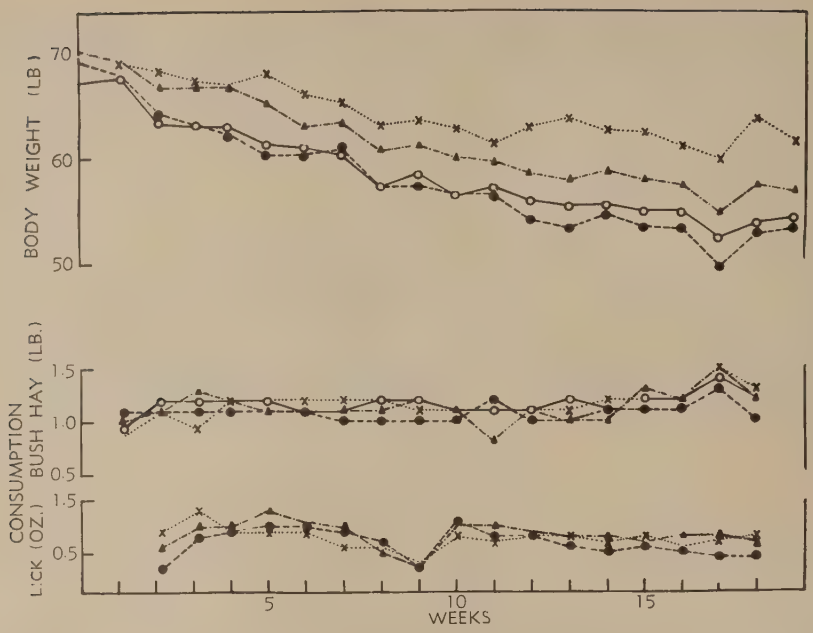

Fig. 1.

Weekly Changes in the Group Mean Body Weight and Bush Hay and Lick Consumption of Four Groups of Merino Wethers.

O———O Group I: Bush hay *ad lib.*

●— — —● Group II: Bush hay *ad lib.* + lick *ad lib.*

△ — . — △ Group III: Bush hay *ad lib.* + lick *ad lib.* + 2.3 oz. crushed grain sorghum per head per day.

× ..... × Group IV: Bush hay *ad lib.* + lick *ad lib.* + 2.3 oz. crushed sorghum + 8 g. urea + 0.6 g. sodium sulphate per head per day.

Table 1.

Group Average Body Weight Changes and Dry Matter Consumption of Sheep Fed a Basal Ration of Bush Hay with Various Supplements.

Group.	Supplement.	Body Weight.			Dry Matter Consumption Per Head Per Day.		
		Initial.	After 19 weeks.	Change*.	Bush Hay.	Lick.	Total.
		lb.	lb.	lb.	lb.	oz.	lb.
I ..	Nil	68	54	−14	1·1	..	1·1
II ..	Lick *ad lib.*	68	53	−15	1·0	0·6	1·0
III ..	Lick *ad lib.* + 2·3 oz. crushed sorghum	69	57	−12	1·0	0·8	1·2
IV ..	Lick *ad lib.* + 2·3 oz. crushed sorghum + 8g. urea + 0·6 g. sodium sulphate	69	62	−7	1·1	0·8	1·3

* None of these differences were significant at a probability of $P<0.5$.

Group IV showed a higher crude protein (N × 6·25) content (7·1 per cent. on a dry matter basis) than the hay fed, due to added urea. Visual examination of the residues from all groups showed that they had a greater percentage of stalk than the hay before feeding. Thus the visual observations and the chemical analyses indicate the selection of the more nutritious portions of the hay. The average wastage of hay from uneaten residues accounted for 0·3 lb. per head per day, or 21 per cent. of the hay fed.

At the termination of the bush hay feeding all sheep were lethargic and unwilling to be exercised.

All sheep with the exception of one animal in Group I, which was the poorest sheep at the conclusion of the experiment, recovered when turned out on pasture, and after 15 weeks exceeded the pre-experimental body weight.

A comparison of body weight changes and dry matter consumption of sheep and cattle fed the same bush hay and supplements is given in Table 2.

Table 2.

COMPARATIVE CHANGES IN BODY WEIGHT AND INTAKE OF BUSH HAY BY SHEEP AND CATTLE* FED THE SAME HAY AND SUPPLEMENTS FOR 19 WEEKS.

Group.	Supplements Per Head Per Day.		Percentage Change in Initial Body Weight.		Bush Hay Intake as a Percentage of Group I.	
	Sheep.	Cattle.	Sheep.	Cattle.	Sheep.	Cattle.
I ..	Nil	Nil	−20	−8	100	100
II ..	Lick	Lick	−22	−9	91	102
III ..	Lick + 2·3 oz. crushed grain sorghum	Lick + 1 lb. crushed grain sorghum	−17	−4	91	110
IV ..	Lick + 2·3 oz. crushed grain sorghum + 8 g. urea + 0·6 g. sodium sulphate	Lick + 1 lb. crushed grain sorghum + 2 oz. urea + 0·17 oz. sodium sulphate	−10	+10	100	125

* From the data of Morris (1958*a*) calculated for the first 19 weeks of the experiment.

IV. EXPERIMENT II.

(1) Design.

Four groups of 13 wethers were fed the following rations:—

Group I : Sorghum silage *ad lib.*

Group II : Sorghum silage, the same amount as fed to Group I, + 8 g. urea and 0·8 g. sodium sulphate per head per day.

Group III: Sorghum silage *ad lib.* + 8 g. urea and 0·8 g. sodium sulphate per head per day.

Group IV: Sorghum silage *ad lib.* + 16 g. urea and 1·6 g. sodium sulphate per head per day.

Supplements of urea and sodium sulphate were sprinkled over the silage and mixed with the upper layers in the trough.

Twice a week the uneaten residues of silage were removed, weighed and discarded after sampling. On the other five days of the week, the uneaten silage was removed and replaced on the freshly added silage.

Sorghum silage feeding continued for 22 weeks until the supply of silage was exhausted. All wethers were then shorn and grazed on a *Paspalum dilatatum* pasture.

(2) Results.

Two animals did not survive the period on sorghum silage feeding, one animal in Group IV died from inanition at 17 weeks and another in Group II died from the same cause after 21 weeks. The remaining 50 animals survived the period on sorghum silage and made rapid body weight gains when returned to pasture.

Table 3.

GROUP AVERAGE BODY WEIGHT CHANGES AND DRY MATTER CONSUMPTION OF SHEEP FED A BASAL RATION OF SORGHUM SILAGE WITH VARIOUS LEVELS OF UREA SUPPLEMENTATION.

Group.	Sorghum Silage.	Supplement.	Body Weight.			Silage Consumption (lb. D.M./day).	Body Weight After 10 Weeks on Pasture.
			Initial.	After 22 weeks.	Change.		
			lb.	lb.	lb.		lb.
I ..	*ad lib.* ..	Nil	63	44	−19	0·73	71
II ..	Same as fed to Group I	8 g. urea + 0·8 g. sodium sulphate	63	50	−13	0·85	76
III ..	*ad lib.* ..	8 g. urea + 0·8 g. sodium sulphate	64	50	−14	0·87	76
IV ..	*ad lib.* ..	16 g. urea + 1·6 g. sodium sulphate	64	49	−15	0·80	76

Group average changes in body weight for the periods of sorghum silage feeding and of recovery on pasture, and the group mean dry matter intake of silage, are given in Table 3. The weekly group average body weight and silage consumption are shown in Fig. 2. Statistical analyses of the group average body weight at 8, 15 and 22 weeks and the linear component of growth rate are given in Table 4.

Silage consumption was greatest in the urea-supplemented groups. Group III ate 21 per cent. and Group IV 11 per cent. more silage than Group I. The consumption of silage by wethers in Group II was greater than in Group I, although the same amount of silage was presented daily to both groups. An excess of silage over consumption was fed to Group I to maintain *ad lib.* intake and feed residues were less in Group II.

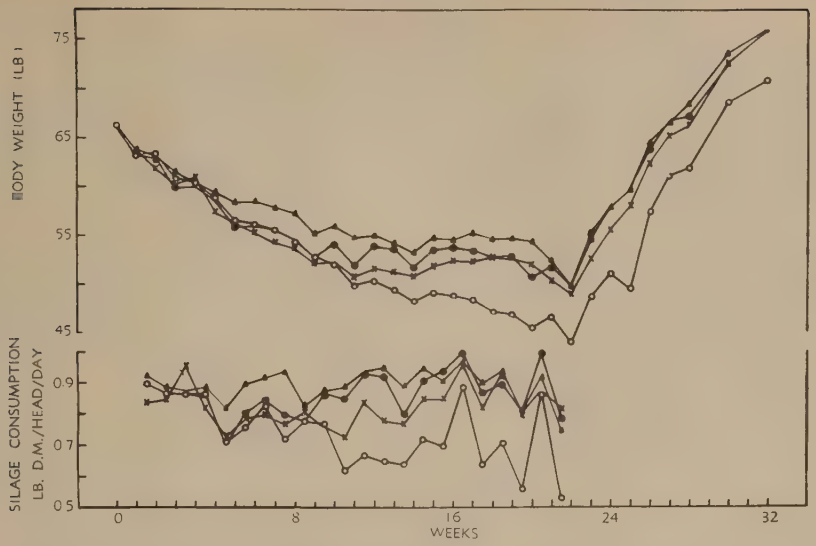

Fig. 2.

Changes in the Group Mean Body Weight of Four Groups of Merino Wethers during Sorghum Silage Feeding (0–22 weeks) and Recovery on Pasture (22–32 weeks) and the Group Mean Daily Dry Matter Intake during Sorghum Silage Feeding.

O———O Group I: Sorghum silage *ad lib.*

●— — —● Group II: Sorghum silage same amount as fed to Group I + 8 g. urea and 0.8 g. sodium sulphate per head per day.

△ — · — △ Group III: Sorghum silage *ad lib.* + 8 g. urea and 0.8 g. sodium sulphate per head per day.

× ..... × Group IV: Sorghum silage *ad lib.* + 16 g. urea and 1·6 g. sodium sulphate per head per day.

Table 4.

Statistical Analysis of the Body Weight and Linear Component of Growth Rate of Sheep Fed Sorghum Silage with Various Rates of Urea Supplementation.

Between Groups.	Body Weight at—			Linear Growth Rate.
	8 weeks.	15 weeks.	22 weeks.	
Group IV greater than Group I ..	NS	NS	†	†
Group III greater than Group I ..	*	†	†	†
Group II greater than Group I ..	NS	*	†	†
Group III greater than Group IV ..	†	NS	NS	NS

NS = Not significant.
* = $P<0.05$.
† = $P<0.01$.

The percentage of the silage presented to the animals that was subsequently eaten was 80 for Group I, 90 for Groups II and III and 84 for Group IV. The crude protein content of the residue from Group I was 4·0 per cent. on a dry matter basis, which is less than the crude protein content of the silage fed out. The crude protein (N × 6·25) content of the residues from Group II was 8·0 per cent., Group III 7·5 per cent., and Group IV 10·6 per cent. The higher apparent crude protein content of these residues was due to the added urea. The crude fibre content of the residue from all groups was greater than the crude fibre content of the silage presented to the animals. Visual examination of the silage revealed that a high proportion of the rejected silage consisted of portions of the stems of sorghum plants and in particular the lower part of the stems. Thus visual observations and chemical analyses indicate the selection of the more nutritious portions of the silage.

The mean wool growth on the tattooed areas was similar for all groups at two months. At four months the mean wool growth was greater in the urea-supplemented groups than in the unsupplemented group, but the difference was not statistically significant at the $P<0·05$ level. The mean greasy wool weight at the conclusion of sorghum silage feeding was 3·0 lb. for Group I, 3·4 lb. for Groups II and III and 3·3 lb. for Group IV.

As the period of sorghum silage feeding lengthened all animals became lethargic and dejected in appearance.

A comparison of body weight changes and dry matter consumption of sheep and cattle fed the same sorghum silage with and without urea supplements is given in Table 5.

Table 5.

Comparative Changes in the Body Weight and the Silage Consumption of Sheep and Cattle* Fed the Same Sorghum Silage and Supplements for 22 Weeks.

Group.	Silage.	Supplements Per Head Per Day.		Percentage Change in Initial Body Weight.		Dry Matter Intake of Silage as a Percentage of Group I.	
		Sheep.	Cattle.	Sheep.	Cattle.	Sheep.	Cattle.
I ..	*ad lib.* ..	Nil	Nil	−30	−16	100	100
II ..	Same as fed to Group I	8 g. urea; 0·8 g. sodium sulphate	1·5 oz. urea; 0·14 oz. sodium sulphate	−21	−9	116	100
III ..	*ad lib.* ..	8 g. urea; 0·8 g. sodium sulphate	1·5 oz. urea; 0·14 oz. sodium sulphate	−22	+11	121	159
IV ..	*ad lib.* ..	16 g. urea; 1·6 g. sodium sulphate	2·5 oz. urea; 0·18 oz. sodium sulphate	−23	+24	111	173

*From the data of Morris (1958*b*) calculated for the first 22 weeks of the experiment.

V. DISCUSSION.

Basal rations of bush hay and sorghum silage fed to groups of Merino wethers in bare yards with shade and water *ad lib.* kept a high percentage of sheep alive for periods up to 19 and 22 weeks respectively. Body weight loss, however, was considerable on the basal rations, averaging 20 per cent. in experiment 1 and 30 per cent. in experiment 2.

Supplementing bush hay with a lick did not decrease body weight loss, while the further addition of 2·3 oz. crushed grain sorghum produced only a slight decrease in body weight loss. When 8 g. urea per head per day was fed in addition to the lick and grain sorghum, body weight loss was only half that on the basal ration of bush hay. Statistical significance was not obtained at the $P<0·05$ level due to individual variations and the small number of sheep per group. Supplementation of the basal diet of sorghum silage with 8 g. or 16 g. urea significantly ($P<0·01$) reduced body weight loss.

Consumption of the basal ration of bush hay was unaffected by supplements. The intake of sorghum silage was increased by 8 and 16 g. urea per head per day. The higher level of urea tended to decrease silage intake of Group IV compared with Group III. This is in agreement with the findings of Peirce, Moule and Jackson (1955), who recorded that rations containing urea were unpalatable to Merino sheep.

Urea has been shown by Peirce (1951a,b) to increase wool production of Merino sheep fed low-protein rations. In Experiment II, at two and four months wool growth on the tattooed areas of the urea-supplemented sheep was not statistically greater than in the unsupplemented group. The mean group greasy fleece weight at the conclusion of the sorghum silage feeding was approximately 10 per cent. greater in the urea-supplemented groups. This was not statistically significant. The within-group variation was large, due to the number of sheep in each group losing part of their fleece through a "break" in the wool.

All sheep fed sorghum silage showed a rapid gain in body weight when returned to pasture, but group differences in body weight at the conclusion of sorghum silage feeding were maintained after 10 weeks on pasture. Sheep fed bush hay did not regain body weight when returned to pasture as rapidly as sheep fed sorghum silage. However, the pasture conditions were more favourable at the conclusion of sorghum silage feeding.

A comparison of the performance of sheep and cattle fed the same basal rations and the same supplements showed that sheep lost a greater percentage of their initial body weight when fed the basal rations; sheep did not respond as favourably to urea supplementation as indicated either by body weight or by intake of the basal ration; and sheep were more selective in the choice of portions of the bush hay and sorghum silage.

Digestibility coefficients of the bush hay for sheep and cattle reported by Morris (1958a) indicated that the coefficients tended to be greater for cattle than for sheep. This is in agreement with the findings of Cipolloni *et al.* (1951), who found, by statistically analysing the results from a large number of sheep and cattle digestibility trials, an average difference of 3 per cent. greater digestibility of the organic matter by cattle than by sheep. This was significant ($P<0{\cdot}01$) for dry roughages but not for silage. However, it appears unlikely that these small differences in digestibility would explain the superior performance of cattle on either bush hay or silage.

The comparative performance of sheep and cattle to urea supplementation in these experiments is in agreement with the general conclusion of Reid (1953), who stated: "The effectiveness of urea as a protein replacement for growing fattening lambs is not as clear cut as it is for cattle." A similar statement was made by Morrison (1956).

The lethargic behaviour of all groups of sheep in both experiments was similar to that described for human subjects (Keys *et al.* 1950) and cattle (Morris 1958a,b,c) on low-calorie diets.

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CONTROL TRIALS AGAINST RED SCALE ON FIGS

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SUMMARY.

Control trials accompanied by seasonal life history studies were conducted with red scale (Aonidiella aurantii (Maskell)) on figs in the Sunnybank district during the period August 1949 to May 1952.

Reproduction by this insect occurred in every month of the year and generally more than 30 per cent. of living females were reproducing. Upsurges in reproduction alternated with peaks in the percentages of living females. Major reproduction peaks were in the periods May to June and December to January, with a minor peak in September. The December-January peak is of major economic importance.

Single applications of lime sulphur (1-35), white oil (1-40), and parathion (0.05%) made three times in a year, including one during the summer reproduction peak, caused only slight reductions in leaf and fruit infestations and were of no practical advantage.

Double applications of these insecticides greatly reduced the percentages of living insects and populations. White oil and parathion were comparable in preventing the spread of infestations to new twigs, leaves and fruit, but parathion had drastic effects on natural enemies and was of no value in preventing early leaf fall.

From these studies white oil is regarded as the only effective insecticide for red scale on figs and two applications 2-3 weeks apart in January are adopted as the standard control.

I. INTRODUCTION.

The commercial growing of figs (*Ficus carica* L.) in Queensland involves only one variety, Brown Turkey, and is confined to the Sunnybank district, adjacent to the Brisbane metropolitan area. From 1946 red scale (*Aonidiella aurantii* (Maskell)) increased in importance as a pest in the orchards and during the 1949 harvest scarcely a fruit was marketed without a scale infestation. In that year control trials against this insect were commenced and seasonal life history studies were made to determine the best time to apply control measures.

II. NATURE AND IMPORTANCE OF INFESTATIONS.

The incidence of red scale on commercial fig trees varies with orchard management. With proper control this pest is of little concern, but it is of major importance if control is neglected. Prior to the present studies some growers made regular summer applications of white oil.

Even in well-managed orchards red scale is known to be present throughout the year. Autumn and winter populations are reduced by the leaf fall and pruning. In the winter and early spring the insects are therefore located on trunks and branches and populations normally appear to be low.

The young in this period settle only in the vicinity of the parents. Young from the summer breeding, however, move upwards onto the new twigs and can cause heavy infestations on both leaves and fruit (Figs. 1 and 2). These infestations affect tree health and reduce both yield and market value of fruit.

III. SEASONAL OCCURRENCE.

From April 1950 to March 1952 regular records were made of the percentages of living adult females and the percentages of reproducing females in the scale populations.

(1) Living Adult Females.

Living adult females of red scale are bright and clear in appearance and turgid with body fluid. Pressure with a scalpel point breaks the scale and body wall and releases fluid. Dead scales are dull and darker in appearance and without body fluid. These differences were used to determine the percentages of living insects in the field samples. The scales were turned for examination, since the same individuals were used in counts of reproducing females.

At least once a month 20 twigs (two from each of 10 trees) known to be carrying scales, were cut approximately the same size and bulked together. This sampling was at about shoulder height and from different aspects of the trees. Twenty-five more or less consecutive adult female insects per twig were examined to a total of 250, obtained in most instances from 10 twigs.

The percentages of living adult females obtained are given in Fig. 3.

The figures show that at all times during the 2-year period the percentages of living adult females were comparatively low. On no occasion was half of the population alive; the maximum reached was 42·8 per cent. The highest peak occurred each year in the late winter-early spring period; a secondary peak occurred in late spring and another peak in the autumn. The lowest seasonal percentages were in December 1950 and January 1952.

In the above seasonal studies mostly non-bearing twigs were used. In other parts of these investigations it was noted that the nymphs from early summer breeding moved onto the new season's twigs. These insects were well grown in February and March and counts of such populations showed that the percentages of living females were higher than on non-bearing twigs. The average, however, was still only about 50 per cent.; rarely was 75 per cent. exceeded. A decline occurred in late autumn and a further decline in late winter; in the spring the percentage of living insects on these twigs dropped to the normal 30 per cent. level of the older twigs.

Fig. 1.

Heavy Infestation of Red Scale on a Fig Leaf.

Fig. 2.

Red Scale on Fig Fruits.

(2) Reproducing Females.

Red scale is viviparous and one or two young may be still present beneath the parent when the next is born. These orange-coloured nymphs can be seen when the parent is turned over for examination. Females while producing young almost invariably give evidence of moisture when pressed with a scalpel point. The individuals with young beneath them and which gave at least evidence of moisture when pressed were therefore regarded as reproducing females.

The living individuals among the females used for determining the percentage of living females were also used for assessing the percentages of reproducing females. The counts, however, were continued until a total of 250 living individuals was examined from each set of samples, and for this purpose all of the 20 twigs were sometimes used.

The percentages of reproducing females are given in Fig. 3.

The figures show that reproduction of red scale on figs occurred in every month of the 2-year period and for the greater part of each year more than 30 per cent. of living females were reproducing. In each year there were three peaks in the percentages of reproducing females alternating with peaks in percentages of living insects; major peaks occurred in the May-June and December-January periods, with a minor peak in September. The times of low percentages of reproduction were in March, August and November, the lowest in each year being in March.

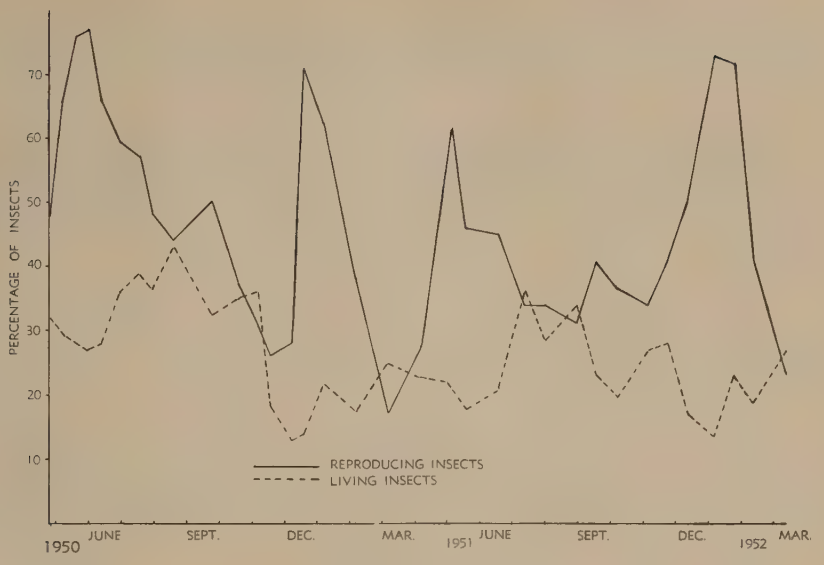

Fig. 3.

Percentages of Living Adult Females and Reproducing Females.

IV. MATERIALS AND METHODS.

Three control trials were conducted in the period from August 1949 to May 1952 to obtain data on the value of white oil and to compare it with parathion. Lime sulphur was also included as a treatment in the trials.

(1) Materials.

The materials used in each of the trials were as follows:—

(*a*) White oil: an emulsion containing 80·0% w/w mineral oil; diluted 1–40.

(*b*) Parathion: an emulsifiable preparation containing 22·4% w/v parathion; diluted 1–450.

(*c*) Lime sulphur: a solution containing 20·0% w/v sulphur as polysulphides; diluted 1–35.

(2) Methods.

Each trial comprised a 4 × 4 randomised layout, using single-tree plots. Trial 1 was of single applications, Trials 2 and 3 of double applications at an interval of 2–3 weeks. Applications were made at first by knapsack spray and later by stirrup pump, at the rate of 1½ gal. of spray per tree without foliage and 3–3½ gal. per tree in full foliage.

Regular twig samples were taken from each tree for determinations of the percentages of living insects before and after spray applications. In all trials only adult females were examined and all discussions relate to those insects.

The value of control treatments against a scale insect such as red scale on figs depends primarily on the ability of the insecticides to kill the insects. To determine this ability to kill requires the counting of large numbers of insects on treated and untreated trees before and at intervals after control applications. The volume of such counting can be an important factor limiting the size of a control trial and the sampling possible during its progress.

In order to facilitate subsequent work the original sampling in Trials 1 and 2 was made for two purposes: (*a*) a statistical analysis to determine an adequate sample, and (*b*) as a pre-treatment count.

Five scale-infested twigs of approximately the same size were taken at random from each of the 32 experimental trees, and on each 50 more or less consecutive insects were examined in groups of 10, and recorded as living or dead. Totals and percentages of dead insects in these counts are given in Table 1.

Table 1.

Numbers and Percentages of Dead Insects.

Site A.			Site B.		
Tree Number.	Dead Insects.	Percentage Dead.	Tree Number.	Dead Insects.	Percentage Dead.
1 ..	179	71·6	5	218	87·2
12 ..	203	81·2	16	222	88·8
18 ..	197	78·8	22	151	60·4
27 ..	184	73·6	31	192	76·8
Mean ..	190·7	76·3	Mean	195·7	78·3
3 ..	188	75·2	7	175	70·0
10 ..	170	68·0	14	183	73·2
20 ..	195	78·0	24	173	69·2
25 ..	194	77·6	29	210	84·0
Mean ..	186·7	74·7	Mean	185·2	74·1
2 ..	145	58·0	6	139	55·6
11 ..	179	71·6	15	172	68·8
17 ..	197	78·8	21	144	57·6
28 ..	151	60·4	32	164	65·6
Mean ..	168·0	67·2	Mean	154·7	61·9
4 ..	175	70·0	8	178	71·2
9 ..	166	66·4	13	197	78·8
19 ..	206	82·4	23	149	59·6
26 ..	162	64·8	30	214	85·6
Mean ..	177·2	70·9	Mean	184·5	73·8

The percentages of dead insects were sufficiently uniform to enable a direct analysis but a transformed variable ϕ was used (where $\% = 100 \sin^2\phi$) so as to provide an equalising effect on the variance for different percentages following the application of control treatments.

The 32 experimental trees comprised two sites and therefore analyses were made for each site on the basis that each 16 trees constituted a 4×4 randomised layout. Analyses of variance are given in Table 2.

Table 2.

ANALYSES OF VARIANCE.

Source of Variation.	Site A.		Site B.		Sites A and B.	
	D.F.	Mean Square.	D.F.	Mean Square.	D.F.	Mean Square.
Rows	3	1,071·03	3	3,121·96		
Columns	3	643·47	3	868·08		
Treatments	3	972·83	3	3,109·56		
Error	6	292·72	6	922·84		
Treatment + Error	9	519·42	9	1,651·75	18	1,085·58
Between Twigs ..	63	423·36	63	402·49	126	412·93
Within Twigs ..	313	137·94	316	130·91	629	134·41

The components of variability considered were:—

(*a*) Between groups of 10 insects on the same twig: σ_1^2,

(*b*) Between twigs on the same tree: σ_2^2,

(*c*) Between trees in the same site: σ_3^2.

The mean squares for sites A and B as a whole are estimates of the following quantities:—

$$\sigma_1^2 = 134{\cdot}41$$

$$\sigma_1^2 + 5\sigma_2^2 = 412{\cdot}93$$

$$\sigma_1^2 + 5\sigma_2^2 + 25\sigma_3^2 = 1085{\cdot}58$$

For the estimate of variability between trees the 9 degrees of freedom plus error was used since no treatment had yet been applied. The estimates for the two sites separately do not agree closely. The estimates between twigs and between groups of insects on each twig, however, agree closely, and since these are the components determining the efficiency of sampling, the lack of agreement between the tree-to-tree estimates is not initially of importance.

From the above estimates it was calculated that $\sigma_1^2 = 134{\cdot}41$, $\sigma_2^2 = 55{\cdot}70$ and $\sigma_3^2 = 26{\cdot}91$. With m twigs per tree and n groups of 10 insects per twig, the variance of a single tree mean would be $\sigma_3^2 + \frac{\sigma_2^2}{m} + \frac{\sigma_1^2}{mn}$, the last two terms representing the increase in variance due to sampling error. The variance for different values of m and n is given in Table 3.

Table 3.

VARIANCE FOR DIFFERENT VALUE OF m AND n.

n (groups of 10 insects).	m (twigs per tree).						
	1.	2.	3.	4.	5.	6.	7.
1 ..	217·0	122·0	90·3	74·4	64·9	58·6	54·1
2 ..	149·8	88·4	67·9	57·6	51·5	47·4	44·5
3 ..	127·4	77·2	60·4	52·0	47·0	43·7	41·3
4 ..	116·2	71·6	56·7	49·2	44·8	41·8	39·7
5 ..	109·5	68·2	54·4	47·6	43·4	40·7	38·7
6 ..	105·0	66·0	52·9	46·4	42·5	39·9	38·1
7 ..	101·8	64·4	51·9	45·6	41·9	39·4	37·6
∞	82·6	54·8	45·5	40·8	38·1	36·2	34·9

On the basis of the above estimates the variance per tree if completely counted would be 26·9. The difference between this figure and those in Table 3 represents increases in variability due to partial counting.

For any given total of insects to be counted the lowest variance would be obtained by taking as many twigs as possible. The proposed counting of 50 insects on each of 5 twigs per tree, involving a total of 250 insects, with a variance of 43·4, would be comparable in efficiency to counting 30 insects on each of 6 twigs per tree, involving a total of only 180 insects.

The efficiency of any sampling method chosen is ultimately dependent on the magnitude of the sampling error. The proposed 5 twigs of 50 insects per twig involved a sampling variance of 16·5—i.e., a s.e. of $\pm$ 4·1. On the data presented from these counts the average value is 60 (= 75 per cent. dead). Thus the uncertainty in the estimate due to sampling variation is $\pm$ 8 (i.e., 62–86 per cent.). For other levels of percentage of dead insects the 95 per cent. fiducial limits would be as follows:

10% or 90%	20% or 80%	30% or 70%	40% or 60%	50%
$\pm$ 8%	$\pm$ 11%	$\pm$ 13%	$\pm$ 14%	$\pm$ 14%

Accepting these limits as satisfactory for the work, any combination of twigs per tree and insects per twig providing comparable variance with 5 twigs of 50 insects each could be used with equal reliance. Consequently, 6 twigs per tree and 30 insects per twig were used in all trials because of the practical advantage in reducing considerably the number of insects to be counted.

During the trials, samples were also taken of leaves and fruit. In each instance six twigs were taken from each tree and counts were made from five consecutive leaves and five consecutive fruit on each twig. In determining the percentages of living insects, 20 more or less consecutive scales were examined on each leaf and each fruit. In addition, records were made of the numbers of clean leaves and fruit, and fruit with fewer than five scales on each.

V. TRIAL 1.

The single applications in this trial were made on Aug. 17 and Dec. 7, 1949, and on Apr. 3, 1950. Twig samples were taken before and after each application; dates of sampling were Aug. 17, Sept. 2, Oct. 18, Nov. 24, 1949, Jan. 9, Feb. 6, Apr. 3 and May 24, 1950. Leaf and fruit samples were taken on Feb. 6, 1950, and further fruit samples on Apr. 3, 1950.

(1) Results and Discussion.

(a) Twigs.

Results of the twig counts are given in Fig. 4. The figures show that on old twigs from untreated trees the percentage of living insects was initially low and in November 1949 was down to 10 per cent. of the population present. On new twigs, as shown in February, April and May 1950, this percentage was much higher.

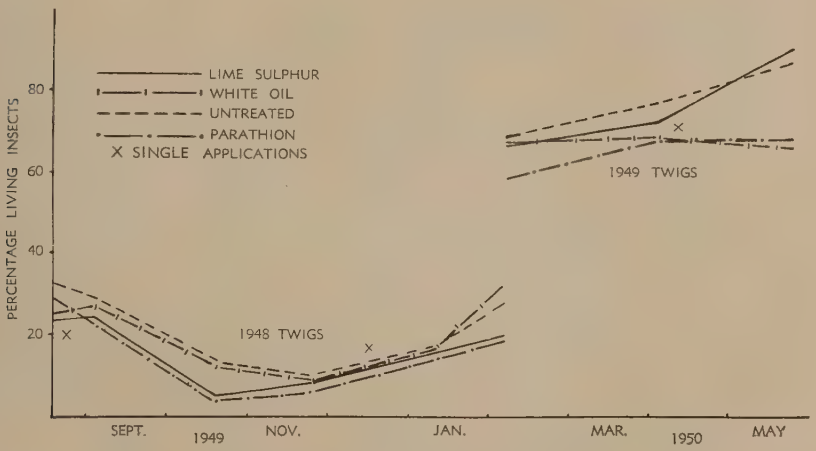

Fig. 4.

Percentages of Living Insects, Trial 1.

Generally the differences between the treatments were small and the figures did not warrant statistical analyses. Each insecticide was regarded as conveying no practical advantage in reducing the percentages of living insects.

(b) Leaves.

Figures showing the results of insect counts on leaves on Feb. 6, 1950, are given in Table 4.

Table 4.

Insect Populations on Leaves.

Treatment.	Mean Insects per Leaf.	Equivalent Percentage Living Insects.	Equivalent Percentage Clean Leaves.
Lime sulphur ..	2·97	90·0	29·8
White oil ..	1·96	88·6	58·2
Untreated ..	8·20	85·7	11·2
Parathion ..	3·50	79·4	45·4
	Differences not significant.		

The figures show that amongst this first generation on the leaves the percentages of living insects were high, and that many of the leaves were infested in all treatments.

(c) Fruit.

Figures showing the results of insect counts on fruit on Feb. 6 and Apr. 3, 1950, are given in Table 5.

Table 5.

Insect Populations on Fruit.

Date.	Treatment.	Mean Insects per Fruit.	Equivalent Percentage Living Insects.	Equivalent Percentage Clean Fruit.
Feb. 6, 1950	Lime sulphur ..	4·16	85·0	30·9
	White oil ..	5·26	91·7	27·6
	Untreated ..	7·58	86·8	9·9
	Parathion ..	3·63	73·8	39·4
		Differences not significant.		
Apr. 3, 1950	Lime sulphur ..	48·58	66·2	2·5
	White oil ..	119·78	72·8	0·9
	Untreated ..	108·17	66·8	0·0
	Parathion ..	47·10	61·2	3·3
		Differences not significant.		Not analysed.

A preliminary examination of fruit in November 1949 showed no evidence of scales. By Feb. 6, 1950, a considerable infestation was present and the percentages of living insects were high in all treatments. Although the mean number of scales present was 7·58 on untreated trees, more than 90 per cent. of the fruit was infested. Fruit on the parathion-treated trees showed half of the infestation of the untreated trees but even with this insecticide more than 60 per cent. of the fruit was infested.

One month later a very heavy infestation was present on the fruit of all treatments and with each insecticide treatment few fruit escaped infestation.

VI. TRIAL 2.

This trial commenced concurrently with Trial 1 but was continued for an extra two years and included yield data. Dates of application were Aug. 17 and Sept. 12, Dec. 7 and 21, 1949, Apr. 1 and 28 and Dec. 6 and 18, 1950. Twig samples were taken on Aug. 17, Sept. 2 and 20, Oct. 24, Nov. 29, Dec. 19, 1949, Jan. 11, Feb. 6, Mar. 27, Apr. 17, May 29, June 21, July 27, Aug. 28, Oct. 20, Nov. 23, 1950, Jan. 9, Mar. 12 and Apr. 9, 1951. Leaf samples were taken on Feb. 6, 1950, and fruit samples on Nov. 29, 1949, Feb. 6 and Mar. 27, 1950. Yield data were recorded for the summer–autumn harvests of 1951 and 1952.

(1) Results and Discussions.

(a) Twigs.

Figures showing percentages of living insects for the various samplings are shown in Fig. 5. Analyses of the data are given in Tables 6 and 7.

The figures show a downward trend from August to December 1949 in the equivalent percentages of living insects in all treatments. This was much greater with the insecticide treatments, particularly white oil and parathion, which in the September 1949 sampling were significantly superior to both the untreated and the lime sulphur treatment. This effect continued into October, although to a less extent with white oil. A delayed beneficial effect was shown in this month by lime sulphur, which together with parathion was significantly better than the untreated.

In December an upward trend was shown in living insects, but an application of the insecticides kept the percentages low in these treatments, and following the second application in this month all insecticide treatments were significantly better than the untreated. The beneficial effect of the insecticides was continued into February 1950.

The percentages of living insects on new twigs in Feburary were much greater in all treatments than on the old twigs (Fig. 5), and although the beneficial effect of the insecticides was evident differences were not significant. During the following two months the percentages tended to become uniform. Following further applications in April the beneficial effect was shown in May, especially with white oil. In June all insecticides were significantly better than the untreated and with parathion this was still so in July and August.

Table 6.

EQUIVALENT PERCENTAGES OF LIVING INSECTS ON TWIGS OF 1948 GROWTH.

Treatment.	1949.						1950.	
	Aug. 17.	Sept. 2.	Sept. 20.	Oct. 24.	Nov. 29.	Dec. 19.	Jan. 11.	Feb. 6.
A. Lime sulphur	20·8	17·6	14·5	5·9	1·8	3·9	1·0	5·3
B. White oil ..	25·6	19·1	3·7	9·1	6·3	3·7	3·9	5·9
C. Untreated ..	37·4	31·0	24·9	17·5	5·9	9·8	21·6	22·6
D. Parathion ..	25·6	14·9	3·8	1·9	1·1	1·5	0·1	1·9
	A<C		B, D « A, C A<C	D, A « C D<A B<C		D « C B, A<C	A, B, D « C D<B	D « C A, B<C

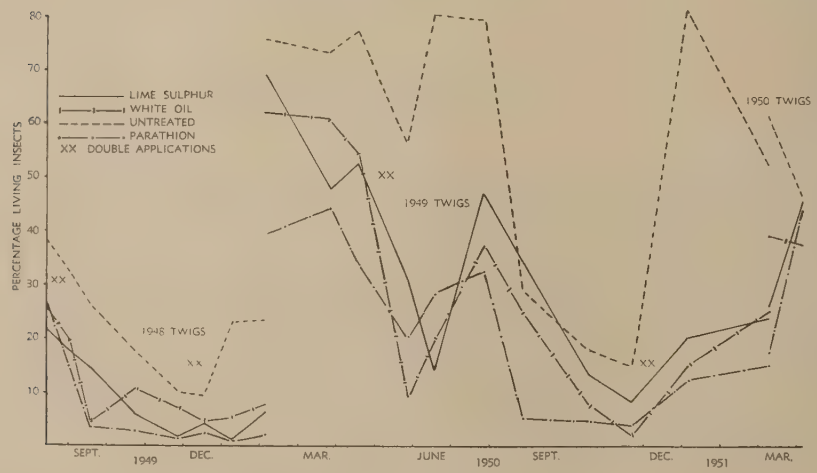

Fig. 5.

Percentages of Living Insects, Trial 2.

Table 7.

EQUIVALENT PERCENTAGES OF LIVING INSECTS ON TWIGS OF 1949 GROWTH.

Treatment.	1950.							1951.		
	Feb. 6.	Mar. 27.	Apr. 17.	May 29.	June 27.	July 27.	Aug. 28.	Nov. 25.	Jan. 9.	Mar. 12.
A. Lime sulphur ..	58·2	50·0	53·8	30·3	23·7	69·3	40·4	8·3	20·1	23·9
B. White oil ..	46·4	61·3	45·7	8·6	23·1	29·1	26·0	1·6	15·0	24·6
C. Untreated ..	75·6	73·1	77·1	56·0	72·1	69·7	25·3	15·4	70·7	52·4
D. Parathion ..	33·8	47·7	40·0	21·3	26·1	9·9	8·5	3·8	12·5	15·0
				B « C D<C	A,B,D <C	D<A, C	D<A	Not analysed.		

Towards the end of 1950 populations generally declined, due possibly to natural enemies favoured by mild winter conditions. Further insecticide applications in December 1950 were followed by slight increases, but an outstanding increase was shown in the untreated trees. In March and April 1951, after effects of the sprays had waned, the percentages of all treatments tended to become uniform especially on the new twigs.

The insecticides also had a marked effect in reducing scale populations on twigs. The mean numbers of insects on the six twigs per tree for each treatment are given in Fig 6.

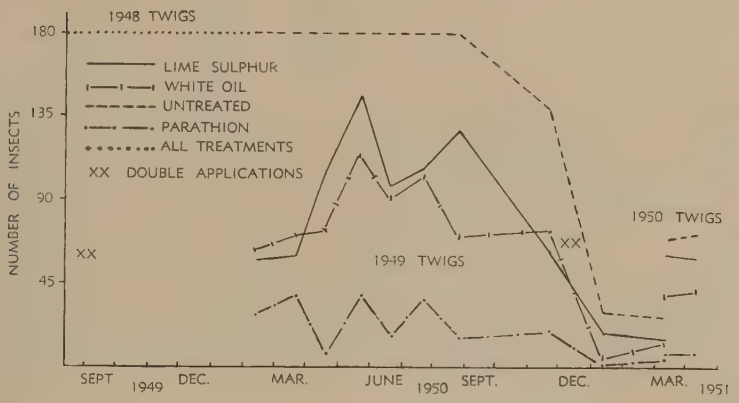

Fig. 6.

Mean Numbers of Insects on Six Twigs Per Tree, Trial 2.

From August 1949 to February 1950, the standard number of 180 insects per six twigs was obtained for all trees in all treatments. This number was also obtained on the new twigs of untreated trees from February to August 1950, but the numbers in the lime sulphur and white oil treatments were about half and still less with parathion. A natural general decline in numbers occurred on untreated trees from August 1950 to March 1951, but the numbers on the treated trees were still lower.

(b) Leaves.

Figures showing the results of insect counts on leaves on Feb. 6, 1950 are given in Table 8.

The figures show outstanding advantages of the spray treatments, especially white oil.

Table 8.

Insect Populations on Leaves.

Treatment.	Mean Insects per Leaf.	Equivalent Percentage Living Insects.	Equivalent Percentage Clean Leaves.
A. Lime sulphur	0·4	85·7	86·1
B. White oil ..	0·1	50·0	99·2
C. Untreated ..	10·8	73·6	31·8
D. Parathion ..	0·3	69·2	89·3
	A, B, D « C		A, B, D » C

(c) Fruit.

All fruit in samples taken in November 1949 were free from scales in all treatments.

The results from samples taken on Feb. 6 and Mar. 27, 1950 are given in Table 9.

Differences in the percentages of living insects between the treatments were slight, indicating that most of these insects must have moved onto the fruit subsequent to the insecticide applications in December. The advantages of the applications were in the marked reduction of this movement and the large percentages of almost clean fruit.

Table 9.

Insect Populations on Fruit.

Date.	Treatment.	Mean Insects per Leaf.	Percentage Clean Fruit.	Percentage Fruit with <5 Scales per Fruit.
Feb. 6, 1950	A. Lime sulphur	1·0	71·6	96·2
	B. White oil ..	0·9	86·4	98·9
	C. Untreated ..	10·8	12·1	40·6
	D. Parathion ..	0·9	76·0	96·6
		A, B, D significantly better than C at 1·0% level.		
Mar. 27, 1950	A. Lime sulphur	3·6	40·9	78·5
	B. White oil ..	15·0	41·3	78·4
	C. Untreated ..	108·2	0·0	3·6
	D. Parathion ..	3·6	44·2	76·3
		A, B, D significantly better than C at 1·0% level.		

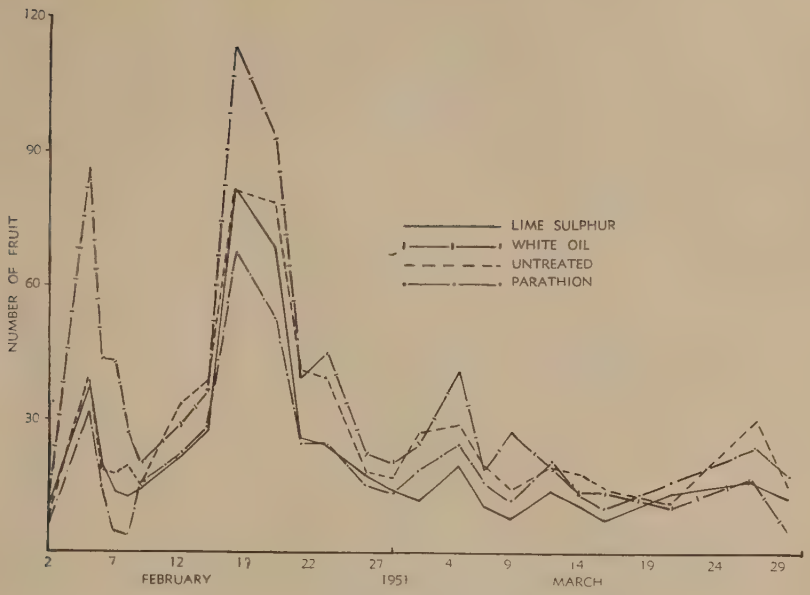

Fig. 7.

Yields in Mean Number of Fruit Per Tree, Trial 2.

Yields of fruit were recorded for the 1951 harvest. Dates of picking and yields in fruit numbers are shown in Fig. 7. Fruit weights were practically parallel with fruit numbers. Totals are given in Table 10.

Table 10.

Mean Yields of Fruit Numbers and Weights, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	510	39·6
White oil ..	788	59·1
Untreated ..	660	53·2
Parathion ..	499	40·2
	Differences not significant.	

Yields from the same trees were recorded for the next harvest (1952) after 12 months of uniform conditions. Results for numbers and weights of fruit are summarised in Table 11.

Table 11.

MEAN YIELDS OF FRUIT NUMBERS AND WEIGHTS, 1952.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	520	25·5
White oil ..	584	32·8
Untreated ..	637	31·8
Parathion ..	452	23·1
	Differences not significant.	

From these figures adjustments of the analyses in Table 10 were possible and the adjusted figures are given in Table 12.

Table 12.

ADJUSTED MEAN YIELDS OF FRUIT NUMBERS AND WEIGHTS, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	538	47·7
White oil ..	753	52·8
Untreated ..	573	47·9
Parathion ..	593	43·6
	Differences not significant.	

The general effect of the adjustments was to bring the means closer together.

VII. TRIAL 3.

The third trial was commenced in another orchard in April, 1950. Double applications were made on Apr. 26 and May 17, and Dec. 6 and 18, 1950. Twig samples were taken on April 26, May 17, June 26, Aug. 2, Sep. 11, Nov. 21, 1950, Jan. 10 and May 1, 1951. Yields of numbers and weights of fruit were recorded in 1951 and 1952.

(1) Results and Discussion.

(a) Twigs.

Results showing the percentages of living insects are given in Fig. 8.

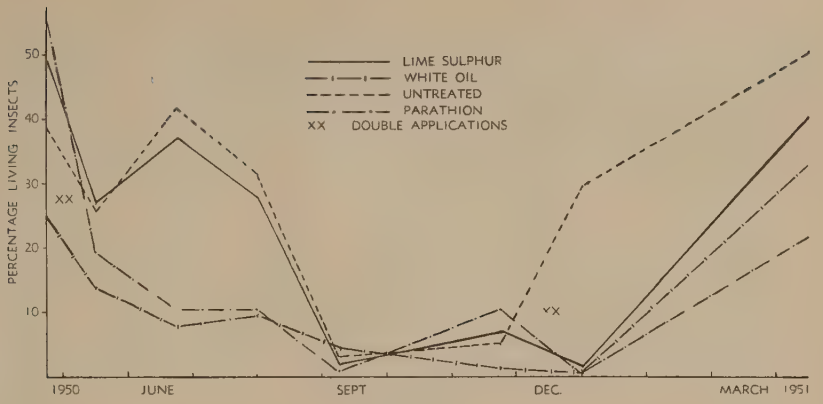

Fig. 8.

Percentages of Living Insects, Trial 3.

A regression in the percentages of living insects was shown in all treatments in May 1950. In June a peak occurred in the untreated plots and was closely approximated by the lime sulphur treatment, but the effect of both white oil and parathion was shown by a further reduction in living insects.

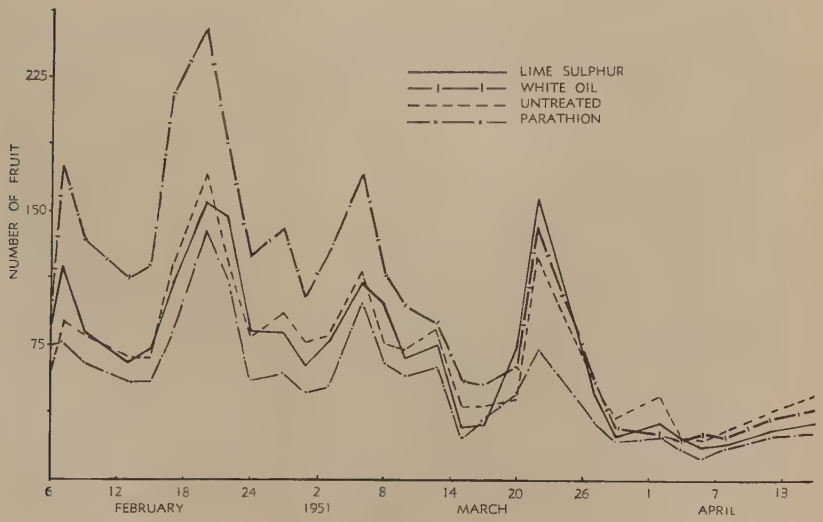

Fig. 9.

Yields in Mean Number of Fruit Per Tree, Trial 3.

The unusually mild wet winter favoured the development of an entomogenous fungus which possibly contributed to the low percentage of living insects in the spring. A slight rise in untreated plots in November was followed by a marked increase but all insecticides had a decided beneficial effect. A sampling in the autumn, however, showed that this effect had waned and the percentages of living insects in all treatments were tending to become uniform.

(b) Fruit.

Numbers of fruit harvested in 1951 as shown by progressive pickings are given in Fig. 9. Weights followed the same general pattern in each treatment. Totals are given in Table 13.

Table 13.

MEAN VALUES OF NUMBER AND WEIGHT OF FRUIT, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	2,008	178·4
White oil ..	2,799	248·8
Untreated ..	1,999	203·1
Parathion ..	1,504	129·8
	Differences not significant.	

Yields from the same trees, after all plots were given uniform conditions for 12 months, were recorded for 1952. Results of these yields are given in Table 14.

Table 14.

MEAN VALUES OF NUMBER AND WEIGHT OF FRUIT, 1952.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	1,966	133·3
White oil ..	2,270	173·6
Untreated ..	1,757	115·3
Parathion ..	1,386	93·6
	Differences not significant.	

From these figures adjustments were made for the 1951 yields and these are given in Table 15.

Table 15.

ADJUSTED MEAN YIELDS OF NUMBERS AND WEIGHTS OF FRUIT, 1951.

Treatment.	Number of Fruit.	Weight of Fruit.
		lb.
Lime sulphur ..	1,906	174·5
White oil ..	2,444	208·4
Untreated ..	2,072	215·5
Parathion ..	1,888	161·8
	Differences not significant.	

As in the previous trial, the adjustments tended to bring the means closer together.

VIII. EFFECT OF WHITE OIL ON LEAF FALL.

In 1951 fig trees generally in the district suffered from premature leaf fall. This was due at least in part to a general infection by fig leaf rust (*Cerotelium fici* (Butl.) Arth.). Differences in the amount of leaf fall were evident amongst experimental trees (Figs. 10–12) although these had uniformly received a copper spray; white oil treated trees carried most foliage (Fig. 12).

Fig. 10.

An Untreated Experimental Tree Almost Bare of Foliage. Photographed Mar. 24, 1951.

Fig. 11.

A Parathion Treated Tree With Sparse Foliage. Photographed Mar. 24, 1951.

A survey of all orchards in the district was made in the period Mar. 13–16, 1951, when insecticidal and fungicidal applications in each were recorded and ratings allotted from 0 to 4 for nil to heavy rust incidence and 0 to 4 for nil to virtually complete leaf fall. The results for the whole district are summarised in Table 16.

Table 16.

Mean Ratings of Fig Leaf Rust Incidence and Leaf Fall.

Treatments.	Leaf Rust.		Leaf Fall.	
	One copper spray.	Two copper sprays.	One copper spray.	Two copper sprays.
No oil spray ..	2·9	1·2	2·2	1·0
Oil spray ..	2·5	0·8	1·0	0·4

The data showed that trees in orchards which had received neither copper nor oil sprays were either bare or almost bare of leaves (Fig. 13). The benefit of white oil in addition to copper sprays was marked and trees which received

Fig. 12.

A White Oil Treated Tree With Complete Foliage. Photographed Mar. 24, 1951.

both retained practically all leaves until the winter (Fig. 14). Amongst experimental trees, those sprayed with both parathion and copper also suffered moderately heavy premature leaf fall (Fig. 11).

The effect of the early leaf fall was also shown in yields. Picking in many orchards, especially those which had not received white oil, did not extend beyond the end of February, and had ceased by the middle of this month in some orchards. Those which had received both white oil and copper sprays continued to yield marketable fruit until April, and in one orchard receiving a late winter oil, a late spring copper and an early summer oil, commercial picking continued until the end of April (Fig. 14).

IX. NATURAL CONTROL.

The winter of 1950 was mild and unusually wet, favouring the development of the entomogenous fungus *Sphaerostilbe coccophila* Tul. During sampling in these months twigs obviously showing the fungus were avoided as much as possible. A normal random sampling was made in August 1950, and examined by the standard counting technique to determine fungal infection. The percentages of obviously infected scales for the various treatments were as follows: lime sulphur 0·0, white oil 25·5, untreated 10·8, parathion 0·5.

Fig. 13.

Trees in an Orchard That Did Not Receive Copper or White Oil Sprays, Bare of Foliage. Photographed Mar. 24, 1951.

Fig. 14.

Trees in an Orchard That Received a Copper Spray in October and White Oil in August and December, 1950, With Complete Foliage. Photographed Mar. 24, 1951.

During the progress of the trials various ladybirds and their larvae were observed commonly on all trees other than those sprayed with parathion. During laboratory examinations the hymenopterous parasite *Aphelinus chrysomphali* Mercet. was noted operating on all trees but rarely on the parathion treated trees.

X. GENERAL DISCUSSION.

The absence of clearly defined generations of red scale on figs presents difficulties in planning a control schedule. Insecticide applications against the constantly emerging crawlers would be ineffective or economically unsound. Control applications therefore must be capable of killing settled insects whether as well-protected adults or as newly settled crawlers with at least some protective secretion. The newly settled crawlers are the more vulnerable and results may be best when treatments are applied following reproduction peaks. The seasonal life history studies showed three breeding peaks—May–June, September, and December–January. The peak occurring in the May–June period is of little economic concern because during the winter months survival is low, the sluggish young settle only on bare branches under or near the parents, and some of the population is removed by pruning. In the remaining population there is a general seasonal downward trend in living adults extending into the spring.

The minor peak in September also is of little concern because there is again a low survival and the general seasonal downward trend in living adults extends into the summer. Few if any crawlers move to or survive on the new actively growing twigs and leaves and no infestation occurs on fruit before the summer reproduction peak.

The summer peak can develop into major importance even from a low percentage of living females in the parent generation. At this time reproduction is at a high level. Survival is high and the young move upwards towards the light to settle on the now hardened twigs and leaves and well-grown fruit. The build-up in infestations on leaves and fruit was shown by these studies to be evident by early February, when both leaves and fruit of untreated trees had a mean of 10·8 adult scales. By the end of March, however, the number on fruit had increased to 108·2. Control, therefore, should be applied immediately after the summer reproduction peak to prevent the development of the destructive action by this generation.

Some of the control applications in the trials detailed above were made in December. These had outstanding effects on scale populations, especially on leaves and fruit, but even by early February some of the fruit on treated trees were infested with adult scales, and by the end of March more than half of the fruit were involved. The benefit of the treatments, however, was evident in that most of these fruit had only a few scales.

As shown by these studies, the summer peak in reproduction extends over December and January. The December applications therefore must have been only partially effective in checking leaf and fruit infestations and a better control should have been possible from January applications. April applications also had an outstanding beneficial effect, but as harvesting commences normally early in February, sometimes in the second half of January, the control applications should be made in January. The value of January applications and of these applications alone during the year have since been confirmed by orchard practice.

In the first control trial in 1949-50, comprised of single applications, some of the insecticides showed early promise of a reasonable control after the initial applications. The December applications, however, did not sufficiently check the population pressure of summer emergence to prevent large numbers of young from moving onto new twigs, leaves and fruit, and this resulted finally in a heavy infestation of fruit in all treatments. Consequently, single applications cannot be regarded as providing a satisfactory control of the scale.

The initial double applications in Trial 2 immediately showed to advantage in reducing the percentages of living insects, and after a few months there were no significant differences between the effects of each insecticide. This pattern followed each subsequent double application. The outstanding feature, however, was that the December 1949 applications suppressed the development of any population pressure from the summer emergence and precluded the movement of many young onto the new twigs, leaves and fruit. By early February untreated trees carried a moderately heavy infestation on more than half of the fruit, and by the end of March scarcely a fruit escaped a heavy infestation, whereas finally on the insecticide-treated trees more than three-quarters of the fruit were clean. The data in Trial 3 were not in such detail but generally confirmed these results.

At the time of commencement of these trials white oil was established as a control for red scale, but a new insecticide, parathion, was claimed by its manufacturers to be an effective control. In Trial 1 there were indications that both white oil and parathion might be of value, but the results were not significantly different from those on untreated trees. In Trial 2 lime sulphur was fairly consistently better than no treatment with respect to percentages of living insects and white oil and parathion rarely showed greater benefit, with little apparent difference between these two. In Trial 3 the ability of each insecticide to kill scale insects was in general similar to that in Trial 2. In the harvest of 1951 there was a suggestion that white oil was significantly superior to parathion, but the difference was reduced on adjusted yields after further yield studies in the following year.

Based on a district-wide survey, white oil proved to be of outstanding advantage over parathion in that trees which had received copper and white oil sprays retained the leaves and yielded for a much longer period than those

receiving copper and parathion. Furthermore, figures from the August 1950 samples showed 25·5 per cent. of the scale population on white oil treated trees infected with entomogenous fungi and only 0·5 per cent. on the parathion treated trees. Parasites and predators were common on white oil treated trees but rare or absent on parathion treated trees.

The parathion concentration now permissible by law is less than one-third of that used in the trials and therefore white oil is regarded as the only effective insecticide for red scale on figs.

The standard control adopted for this pest (Brimblecombe 1951) is two applications of white oil (1–40) spaced 2–3 weeks apart in January each year.

XI. ACKNOWLEDGEMENTS.

Thanks are due to those orchardists who made trees available for experimental purposes. Mr. P. B. McGovern, Departmental Senior Biometrician, was responsible for the analyses of the trial data obtained and provided detailed information on the sampling technique.

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